

Deliverable Report



Extending Design Thinking with Emerging Digital Technologies

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## Abbreviations

AP	Activity Plan
ChoiCo	Choices with Consequences
DT	Design Thinking
ET	Emerging Technologies
Exten.(D.T.) <sup>2</sup>	Extended squared
LNU	Linnaeus University
MaLT2	Machine Lab Turtleworlds 2
NKUA	National and Kapodistrian University of Athens
NTNU	Norwegian University of Science and Technology
OU	Open University
SorBET	Sorting Based on Educational Technology
PD	Professional Development
TCD	Trinity College Dublin
UGent	University of Ghent
UI	User Interface
WP	Work Package

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## 1 Summary

This deliverable addresses Work Package 5: 'School Interventions', led by NKUA in Task 5.3: 'Second and Third Cycle interventions in schools' (M12-M30). It specifically focuses on the Second Cycle of school interventions, implemented during M17-M21 of the project. Task 5.3 concerns the iterative implementation of the Exten.(D.T.)<sup>2</sup> interventions designed in Task 5.1 in a web of schools and the collection of data for the evaluation in WP7. Cycle 2 of school interventions was based on the activities designed in Task 5.1, involved 18 schools (target 20-25) and 639 (target 500-700) participant students (~25-30 students/school). For the co-design of the Cycle 2 of school interventions, NKUA updated the Activity Plan Template, taking into account Year 1 WP7 recommendations (D7.2). The updated version of the template and thus the design of the Year 2 school interventions, was structured according to the five (5) phase Exten.(D.T.)<sup>2</sup> Design Thinking Model, developed by the partners of the project: (Empathise and Understand, Define and Ideate, Rapid prototyping and Iteration, Sharing and Feedback, Respond and Deliver), and concerned the creation of a final digital artefact (e.g., a digital simulation) using the Exten.(D.T.)<sup>2</sup> technologies, to be used by others and provide a solution to a real-world problem.

The model and the design process of the Activity Plan Template - Year 2 are described in detail in D5.1. NKUA collaborated with WP3 so that the template was provided to teachers and researchers in multiple forms through the ExtenDT2 and nQuire platforms. This deliverable includes a description of the intervention implementation process of Year 2 school interventions (Section 3), an overview of Year 2 interventions context and participants; the activity plans that were co-designed and implemented by partners and teachers (Section 4), followed by a reflection on the implementation of the interventions (Section 5) and a concluding discussion on future steps (Section 6).

All the Activity Plans that were designed and implemented as part of the Cycle 2 of Exten.(D.T.)<sup>2</sup> interventions are presented in a separate complementary supplement document Appendices A-S. A Final (updated) Report on 2<sup>nd</sup> and 3<sup>rd</sup> Year Implementations will be submitted in M34 (30 June 2025).

## 2 Introduction

### 2.1 Purpose and Objectives

The Cycle 2 of school Interventions in the Exten.(D.T.)<sup>2</sup> project (M17-M21) integrated the use of the extended technologies of the project. Teachers and researchers co-designed activities and resources using the ExtenDT2 platform (<https://extendt2.com/>) (see D5.4). Year 2 school interventions engaged 639 students in Design Thinking (DT) projects that dealt with STEAM and socio-scientific problems (e.g., cybersecurity, sustainable cities, fashion and travel,

recycling). The task also included the data collection for evaluation purposes (WP7). An in-depth analysis of the data regarding the process of designing, implementing, and evaluating DT activities in schools will be provided by D7.2. Following, and in the context of the design-based research methodology (Bakker & Eerde, 2015) employed by the project, these recommendations will inform:

- Further refinement of the Exten.(D.T.)<sup>2</sup> DT model and the DT Activity Plan Template as a tool that supports the co-design of school interventions.
- Co-design of digital educational resources for supporting digital DT (WP3) in collaboration with teachers, e.g., digital games, 3D artefacts, supporting and training material, using the extended digital technologies from WP4.
- Refinement of the project technologies.
- Further design of the Authorable Learning Analytics Dashboard component (WP4), so to support teachers to monitor students’ progress and performance during collaborative DT projects with emerging technologies (ET).

The collection and analysis of the data will also provide feedback on the use and usefulness of the evaluation toolkit (WP7) and its further refinement so that it provides enough data for the understanding of the interplay between pedagogy, technology, content, school context, students, and teachers during DT methodology based educational activities with ET.

## 2.2 Connection to other Project Activities

The work reported in this deliverable (Figure 1) is connected to:

- WP2: The DT framework
- WP3: The co-design of educational activities and resources
- WP4: The design of the digital tools
- WP7: Data evaluation

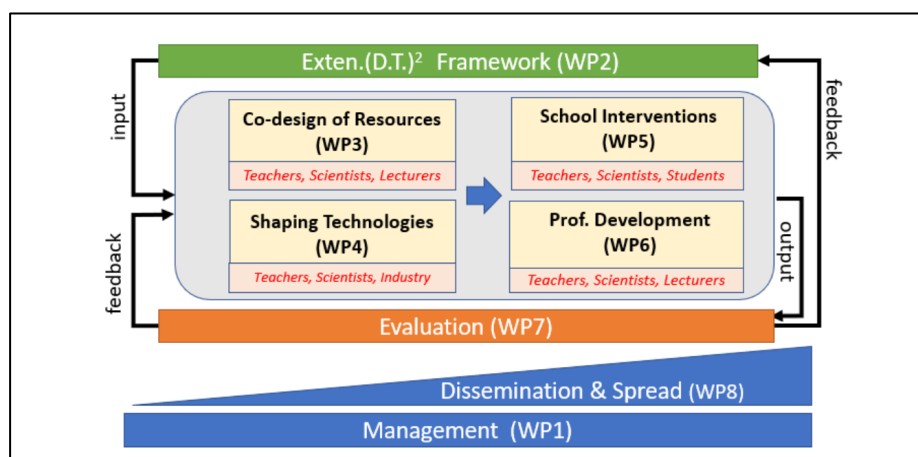


Figure 1: Relationships between WP5 and other WPs

Specifically, school interventions of WP5 derive from **WP2** developments on the DT framework, which sets the context for the design of the “Design Thinking Activity Plan Template” that partners and teachers used to design DT activities (see D5.1). WP5 is also connected with **WP3** (Co-design of Educational Resources and Material), which involves the co-design and co-development of: a) educational activities with the project technologies, b) supporting material as to how to use these activities with learners, and c) teacher training material to support the design and implementation of Digital Design Thinking activities. WP5 connects closely with **WP4** (Shaping Technologies), which concerns the extension of existing digital tools “*with emerging technologies for the digital enhancement and transformation of Design Thinking learning*”. Finally, WP5 also serves to collect data for the objectives of **WP7** (Evaluation), which “*provides evidence for the development and refinement of tools and activities as used and implemented by teachers in the project*”. The analysis of the data collected during Year 2 school interventions (M17-M21) is reported in D7.2. The recommendations that emerge from the WP7 data analysis will further inform the design of the Activity Plan Template, the co-design, implementation process of school interventions and the data collection of Year 3 of the project.

### 3. Implementation Process of Year 2 Exten.(D.T.)<sup>2</sup> School Interventions

The Exten.(D.T.)<sup>2</sup> School Interventions follow the participatory design-based research methodology of the project (Bakker & Eerde, 2015; Barab & Squire, 2016). After three Cycles of design-implementation-evaluation the project aims to provide useful insights regarding the design of efficient educational materials, technologies and activities based on the DT methodology. This deliverable focuses on the implementation of the Cycle 2 interventions that took place in M17-M21.

In Year 1 of the project and for purposes of consistency across the six countries where school interventions are being implemented, NKUA developed a Design & Implementation Protocol to describe the universal procedure that is to be followed across all partners. For the Year 2 interventions, we updated this protocol, integrating preparations related to the use of the Exten(D.T.)<sup>2</sup> technologies and Year 2 evaluation objectives. The protocol involves three stages: Preparation (WP3 & WP5), Implementation (WP5) and Evaluation/Reflection (WP7).

**Preparation** of the school intervention includes:

- Partners contact teachers through open calls or existing school networks.
- Teacher training and co-design of Activity Plans (in collaboration with WP3).
- Teachers and partners contact with schools and get permission for the conduction of the study, children participation and research and AI data collection.

- Partners and teachers issue the necessary permission for research in school context and data collection (differs in every country (see WP7 deliverables).
- Partners collect the informed consents from students, parents, and teachers (see WP7 deliverables).
- Partners and teachers set up the ExtenDT2 platform (see D4.1), creating credentials for teacher and students' groups.
- Researcher and teacher co-design activities on the ExtenDT2 platform and assign them to student groups.
- Researcher and teacher select focus groups.

**Implementation** of the school intervention includes:

- Students answer the pre-surveys (see D7.2).
- Teachers and researchers running and monitoring the DT projects follow the five phases of the Exten.(D.T.)<sup>2</sup> DT model (Empathise and Understand, Define and Ideate, Rapid prototyping and Iteration, Sharing and Feedback, Respond and Deliver).
- Teachers and researchers capturing the learning process with different means throughout the activity (observations, video/audio recordings, screen capturing, and, in some cases, learning analytics data).
- Students answering the post-survey.
- Teachers answering the post-intervention interview (for the interview structure see D7.1 and D7.2).
- Focus group students answering post-intervention interviews (for the interview structure see D7.1 and D7.2).

**Evaluation/Reflection** of the school intervention includes:

- Data transcription, anonymization, and safe storage.
- Data analysis report by each partner performing interventions (for WP7).
- Recommendations and best practices informing the next Cycle of technology development, interventions preparation and delivery (for WP3, WP4 & WP5).

Below we describe the preparation and implementation stages of Year 2 school interventions. Evaluations and reflections are reported in D7.2.

### 3.1 Preparation of Year 2 Exten.(D.T.)<sup>2</sup> School Interventions

#### 3.1.1 Teachers' background

The co-design preparation and implementation processes of school interventions were discussed and finalised during a WP5 meeting with all partners that was organised by WP5 in collaboration with WP3. Following this the Exten.(D.T.)<sup>2</sup> partners organised a series of co-design workshops in collaboration with WP3, to introduce teacher participants on the scope

of the project and technologies, and provide them with supporting material to design DT activities with the use of Exten.(D.T.)<sup>2</sup> digital technologies. Together with the Activity Plan Template (D5.1), NKUA and OU, updated the set of supporting material on the use of the project's technologies which is shared through the project website (<https://extendt2.eu/technologies/>). Teachers were provided with written and 1-minute video tutorials, guides, manuals, and relevant research papers regarding DT methodology and project technologies. Additionally, two online versions of the DT Activity Plan Template were created in; a) (<https://nQuire.org.uk/mission/extendt2-activity-plans-for-teachers/data>) the nQuire platform in the form of nQuire mission to allow teachers design a DT Activity Plan, share it with others and ask for their comments, and b) in the ExtenDT2 platform (<https://extendt2.com/>) to facilitate teachers to design their activities directly through the platform and export it to a .pdf form (for a detailed description of the ExtenDT2 platform see D4.1).

For Year 2 interventions teachers were reached either through an open call (OU, NTNU) or via teacher networks of the partners (NKUA, LNU):

NKUA contacted teachers through the teacher network of the Educational Technology Lab and organised two workshops to introduce them to the project.

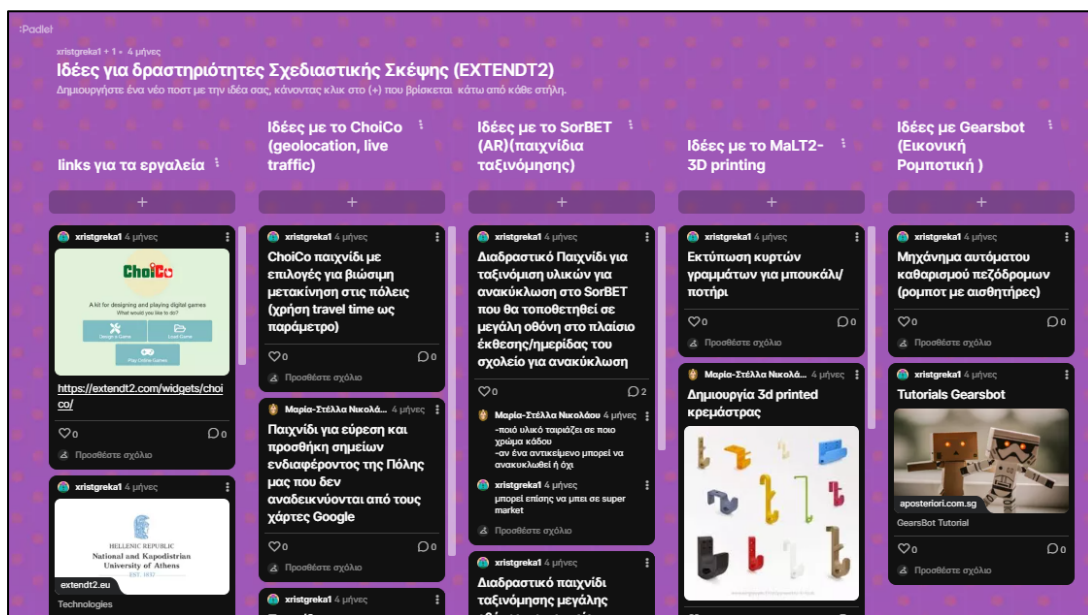


Figure 2: Screenshot from the Padlet board used during brainstorming session by NKUA teachers <https://padlet.com/xristgreka1/extendt2-69q6a399t5k23r7r>

Seven (N=7) teachers participated in two co-design workshops. Two (N=2) of them are mathematics educators, two (N=2) are ICT educators, one (N=1) is a geography and science educator, one (N=1) is an engineering teacher and one (N=1) is a primary teacher. Apart from the primary teacher, all of them are educators in secondary education while the engineering educator teaches in a vocational school. Six (N=6) had used the project technologies before

either in their educational practice or professional development (PD) programs. Two of the teachers had also implemented a DT activity during Year 1 of the project. The rest of them had not implemented a DT activity with their students previously. They all developed and implemented activity plans.

The first workshop aimed to familiarise the teachers with the project's objectives and the technological tools they would be using. In the second workshop, teachers shared their initial ideas on DT projects and one or two researchers were teamed with each educator to continue co-designing via 1-1 meetings. As a result, eight (N=8) Activity Plans were designed and implemented during the Year 2 of school interventions: three (N=3) MaLT2, three (N=3) ChoiCo activities, one (N=1) GearsBot activity, and one (N=1) SorBET activity.

The teachers that implemented DT school interventions in collaboration with OU had previous experience with the project's methodology and technology as they also participated in the pilot interventions during the Year 1 of the project.

NTNU contacted teachers and schools through the teacher network of the researchers involved in the project including contacts that were built during the activities of Year 1 pilot interventions. During Spring 2023 NTNU also had a meeting in Trondheim Municipality with key school stakeholders, including school headmasters from the region, where new contacts were initiated and two new schools agreed to run interventions. A full day workshop was organised in February 2024, with activities related to the project's objectives, co-design and PD activities. In this workshop, 5 participants who are instructors (as pre-service teaching educators) and students in ICT subjects focusing on programming, created 2 activity plans (working in a group of 2 and a group of 3). These were part of the workshop and were not intended to be implemented in a classroom to be part of the school interventions.

After the initial contacts with schools and teachers, starting in the academic Year 2023/2024, 1-1 meetings followed with teachers, either in person or on-line. In these meetings, the researchers went through with the teachers in detail about the Exten.(D.T.)<sup>2</sup> project activities, the specifics and requirements for the school implementation, all the technologies and the co-design of the activity plans (AP). Eleven (N=11) teachers were engaged in the implementation of interventions in schools, and all received information on the project including the co-design materials, technologies and PD. One had implemented a DT activity during the Year 1 of the project (using ChoiCo). None of the other teachers had worked with the project's activities before. One teacher (mathematics education) co-created an AP about recycling with the researchers and implemented the activity (using GearsBot). One teacher (pre-service for ICT/computer science education and student) co-designed 2 AP that were also implemented (one using GearsBot and one SorBET). The other teachers worked mainly with science and ICT related subjects (N=6), mathematics (N=1), or various subjects in primary

education or elementary (N=2). For the AP implemented at the end, some teachers decided to use the ready-made AP (that were sometimes used as examples in our interaction with them). However, in all cases they made some adjustments based on the background, age or other needs of the students/classroom and thoroughly examined and amended the plan as appropriate.

LNU approached an EduTech enthusiast (English Teacher and IT pedagogue) committed to improving pedagogical systems in Swedish schools. Through this person LNU contacted three of his colleagues (teachers in Swedish, Social Sciences and English) at Thoren Framtid School (Växjö, Sweden) and organized initial briefing sessions held over two days, each lasting about an hour. This set the stage for subsequent school interventions. The teachers had no previous experience with DT methodology or the project's technologies. The briefing took place in April 2024. Before school interventions an introductory workshop for students from one school (76 students) was organized at LNU with guest speaker, Juan Velasquez, a senior lecturer and expert in DT. This workshop aimed to familiarize the students with the concepts and significance of DT and introduce the Exten.(D.T.)<sup>2</sup> learning tools. Following the briefing, consent forms were sent to parents on student participation in the project. The intervention commenced in May and spanned three weeks. Students were divided into three groups: Yellow, Orange, and Red. Each group participated in seven sessions, totalling 21 led by three teachers. Each session lasted approximately 1 hour and 15 minutes. Of the 76 students, aged 14-15, 46% were male and 54% female. The intervention curriculum centred around "Save the Bees" based on the Beekeeper's game, and utilising ChoiCo as the technological platform. Students learnt about DT, its importance in learning, and its impact on their choices. The sessions included class presentations, interactive activities, and hands-on practice with ChoiCo, allowing students to create mind maps that reflected their mental models and understanding of the project. Throughout the intervention, daily activities and observations were documented, focusing on the intervention process and the design of the ChoiCo game. Students effectively grasped the concepts and demonstrated their understanding by creating their own games. The hands-on practice facilitated a deeper comprehension and engagement with the project, resulting in a successful learning experience for all participants.

TCD collaborated with a secondary school computer science teacher for a co-design workshop. The workshop provided a brief overview of DT, the project's technologies and included time for co-designing the activity plan. The teacher had limited knowledge of DT, specifically from the Bridge21 programme offered at TCD, possessed advanced computer skills relating to coding, but had no prior experience using the project's technologies. During the co-design workshop, the teacher and researcher collaboratively devised the DT activity plan, which was implemented throughout 7 sessions.

UGent approached several teachers by attending two science education fairs. Interest was also generated through traditional channels for tuition in UGent. In total, there were 15 teachers with diverse backgrounds: sciences (10), moral science (2), others (3). The DT workshop was meant for students 16 years+. Attendees included an educational supervisor and three higher educational teachers (students 18 years+). One participant was already working on a project using DT. None of the participants had used ChoiCo before. Four teachers designed and implemented DT Activity Plans.

As a result, 28 teachers (NTNU (11), NKUA (7), LNU (3), OU (2), TCD (1) and UGent (4) were involved in the co-design and implementation of 19 (N=19) in total Activity Plans in 18 (N=18) schools in six (N=6) countries (see Section 4.3.1 for an Overview Table of all Year 2 Activity Plans and Appendices A-S for their detailed description). All teachers who ran an intervention read and signed a [consent form](#) for taking part in the project and for data collection. More information about the design and implementation of co-design workshops with teachers can be found in D3.1 and D3.2.

### 3.1.2 Parents and students contact and collection of consent

Before the study, involved researchers issued the necessary permission for implementing research in school context, based on their country legislation. Such permission was issued for the interventions in Greece (NKUA), Norway (NTNU), Sweden (LNU), Ireland (TCD) and the United Kingdom (OU). For Belgium (UGent) this was not required.

After having designed the APs, the teachers informed the school, the students and their parents, about the research aims and scope and the data collection and analysis processes and asked for their consent to participate. To do so, they distributed a hard copy of the [informed consent documents](#) for Year 2, developed by WP7, translated in their local language. The consent documents for each intervention included: a) [a child information assent](#), b) [the teachers' information and consent](#), c) the parents' information and consent. The consent forms included information about the research purposes and process, the collection, usage and storage of research and Learning Analytics data, how students could leave the study at any time and contact information. Students aged 16+ signed a [student 16+ information and consent document](#). The signed informed consents are stored by each partner at their university.

### 3.1.3 Delivery process

To support teachers to deliver the activities, it was decided that at least one researcher would take part in the intervention along with a teacher. Researchers had a supportive role during the process giving support to technical problems, facilitating both the activity implementation and data collection. NKUA updated the two intervention [checklist documents used in Year 1](#) according to the [updated evaluation toolkit](#) (D7.2) for Year 2. These documents describe the

actions that must be performed before, during and after each intervention session by teachers and researchers respectively. Teachers were provided with the [Teacher Checklist](#) and researchers with the [Researcher checklist](#). Below an overview of teachers’ and researchers’ actions before, during and after the intervention sessions is provided.

### Before the first Session

The primary change in the implementation of school interventions in Year 2 was the use of the ExtenDT2 platform and the automatic Learning Analytics data collection of students’ interactions with the learning tools (see D4.3). Each teacher, with the help of a researcher, had to prepare activities for their students and assign them to groups. An administrator account was created for each partner involved in the project. Initially, the administrator registered the teachers who would implement the activities, using their names and email addresses. Teachers then received their password to log into the ExtenDT2 platform as educators, where they could design activities their students would work on during the intervention (Figure 3). In the screenshot the teacher has created 3 activities on the ExtenDT2 platform and assigned the third activity “Prototyping/Iteration” in five groups.

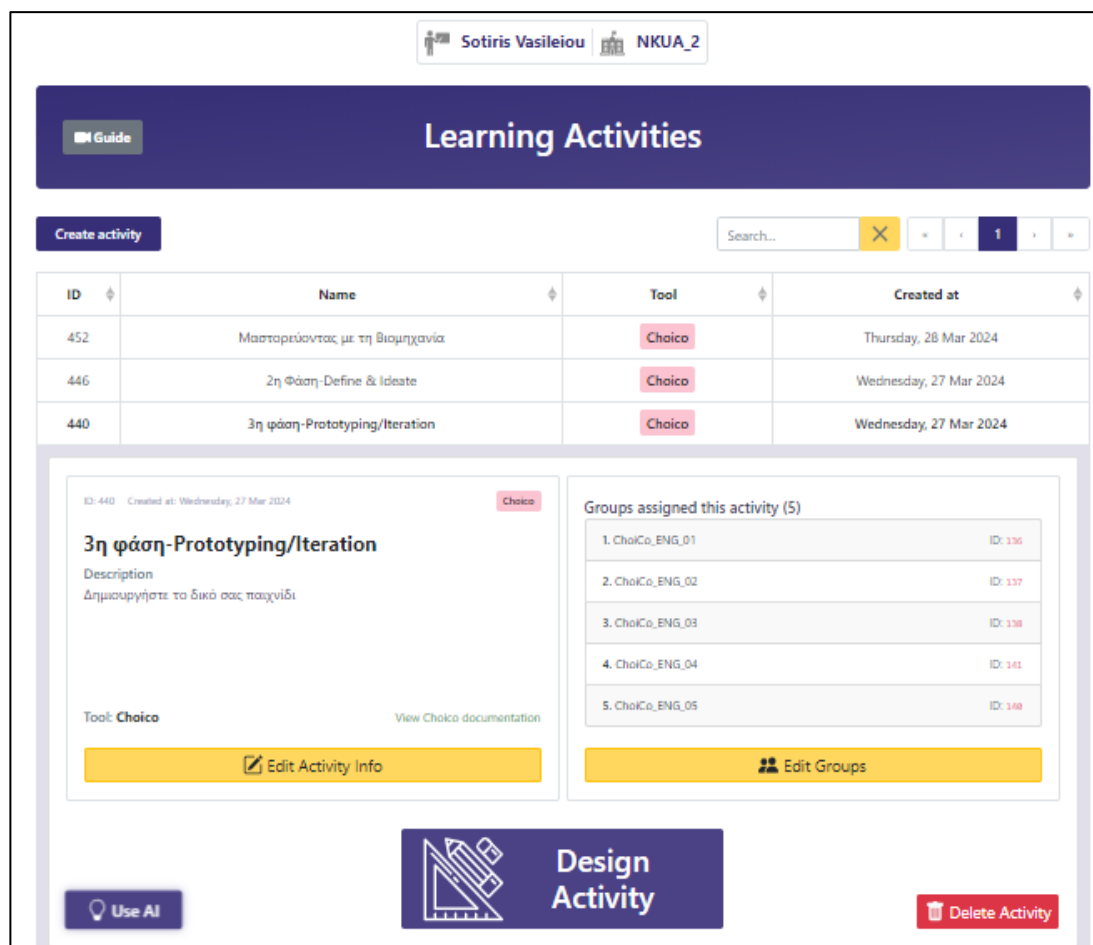


Figure 3: Example of activities designed for an intervention in the ExtenDT2 platform

The teachers then informed the researcher and the administrator about the number of student groups so that the partner's administrator account could create a learner ID for each group. Once the learner IDs were created, teachers could assign the activities they had designed to the respective groups. These activities in most cases included already existing ChoiCo or SorBET games or MaLT2 'half-baked' microworlds for students to debug, helping them understand the functionalities of each tool (see Section 4.3.4 Teaching Methods & Materials of this document). A more detailed description on how students and teachers used the ExtenDT2 platform is provided in D5.4.

In addition to preparing platform credentials and activities, teachers also needed to create a class in nQuire and generate individual nQuire credentials for each student so that they could log in individually, contribute to all group missions during the 'Empathise and Understand' phase, and provide feedback during the 'Sharing and Feedback' phase. Each partner requested teacher credentials from OU. Once received, teachers logged into nQuire to create their classes and generated the necessary student credentials for the intervention (Figure 4, Figure 5).

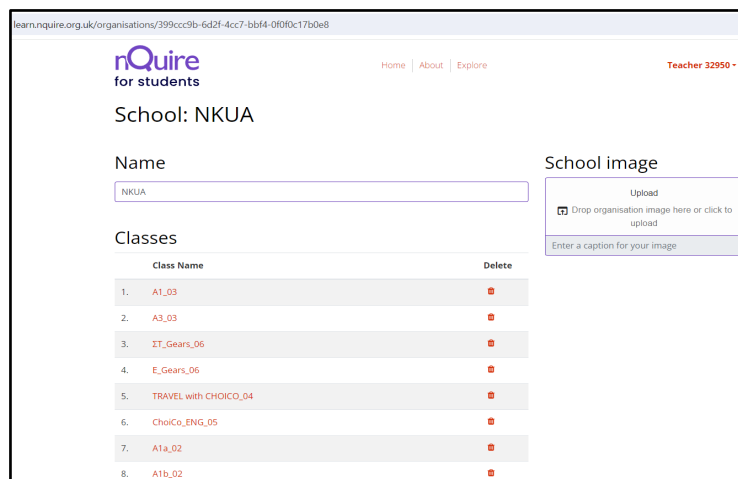


Figure 4: Screenshot from the nQuire platform where teachers can create their classes

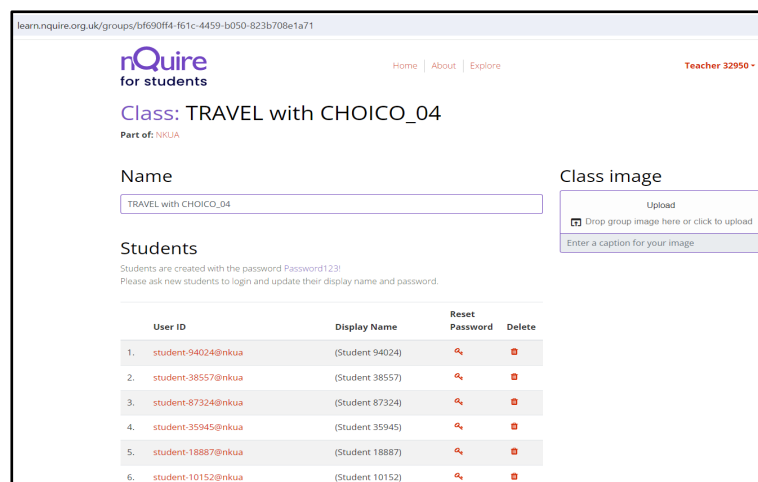


Figure 5: Screenshot from the nQuire platform where teachers can create their students' credentials

## First Session

Teachers informed the focus group students about their selection and asked for their verbal consent. Where a student did not consent to being video recorded, teachers had to inform the researcher so that he/she would set the camera accordingly. Next, teachers provided each student their participant number and the “Student Pre-Survey” in digital (Qualtrics) or [printed form](#). Researchers ensured that the audio/screen recording software was installed and ran correctly on the focus groups’ computers. Before the intervention, researchers took a picture of the spatial arrangement of the classroom/lab where students would work. Finally, researchers were responsible for collecting the students’ pre-surveys where students did not use a Qualtrics link but a paper-based version of the survey.

## Each Session

At the beginning of each session, teachers and researchers ensured that cameras, microphones, and screen recording software were set up and ready to record the session. At the beginning of each session teachers and researchers made sure that students’ nQuire credentials and the learner ID for each group were available. During the activities a researcher filled in the “[Observation Protocol](#)” document. After the end of each session researchers transferred the audio/video recorded data and students’ artefacts to hard drives and deleted them from school computers for data protection reasons. They also collected students’ artefacts in digital or physical form (e.g., demo games, handwritten notes, constructions, drawings).

## After the last session

Teachers distributed and collect the post surveys, with the help of the researcher, in digital or [physical form](#). After the intervention, teachers with researchers arranged for student interviews following the “[Student Interview Protocol](#)”. Researchers also arranged an interview with teachers following the “[Teacher Interview Protocol](#)”. To assure objectivity and reliability, in some countries teacher interviews were conducted by researchers that did not take part in the intervention. Finally, researchers were responsible for collecting and preparing all available data for analysis, including transcription of student dialogues and interviews, data anonymization and uploading students’ answers in Qualtrics where printed surveys had been used.

### 3.1.4 Data collection

Interventions also included the data collection process for evaluation purposes. In Year 2 partners used the [Year 2 evaluation toolkit](#) developed in WP7 to collect survey, video, screen and audio recording data to capture various aspects of the whole process, and gaining an in-depth understanding of the learner experience during the activities. To keep track of the data collection process, NKUA created an [online database](#) which partners fill in information for each intervention. Table 1 below shows the data collected during Year 2 school interventions.

Table 1: Data collection during Year 2 school interventions

Intev. Code	No of students	Student Surveys	Observation Protocol	Observation (written/ video/ screen/ audio)	Student Artefacts	Student Interviews	Tutor Interview
NKUA0201	22	yes	yes	yes	yes	yes	yes
NKUA0202	44	yes	yes	yes	yes	no	no
NKUA0203	30	yes	yes	yes	yes	yes	yes
NKUA0204	21	yes	yes	yes	yes	yes	yes
NKUA0205	14	yes	yes	yes	yes	yes	yes
NKUA0206	14	yes	yes	yes	yes	yes	yes
NKUA0207	5	yes	yes	yes	yes	yes	yes
NKUA0208	13	yes	yes	yes	yes	yes	yes
UGHENT0201	60	yes	yes	no	yes	yes	yes
UGHENT0202	11	yes	yes	no	yes	yes	yes
UGHENT0203	18	yes	yes	no	yes	yes	yes
UGHENT0204	13	yes	yes	no	yes	yes	yes
OU0201	28	yes	yes	yes	yes	yes	yes
OU0202	8	yes	yes	yes	yes	yes	yes
NTNU0201	20	yes	yes	yes	yes	yes	yes
NTNU0202	19	yes	yes	yes	yes	yes	yes
NTNU0203	21	yes	yes	no	yes	no	no

NTNU0204	47	yes	yes	no	yes	no	no
NTNU0205	51	yes	yes	no	yes	no	no
NTNU0206	26	yes	yes	no	yes	no	no
NTNU0207	18	yes	yes	no	yes	no	no
NTNU0208	12	yes	yes	no	yes	no	no
NTNU0209	11	yes	yes	no	yes	no	no
LNU0201	76	yes	yes	yes	yes	yes	yes
TCD0201	18	yes	yes	yes	yes	yes	yes
TCD0202	19	yes	yes	yes	yes	yes	yes

## 4. Exten(D.T.)<sup>2</sup> School Interventions

### 4.1 Context and Participants

During M19-M22, six (N=6) project partners, NKUA, NTNU, OU, LNU, UGent and TCD organised and implemented twenty-six (N=26) school interventions based on nineteen (N=19) relevant APs co-designed by teachers and researchers. Below we provide an overview of the interventions in Year 2 schools in terms of the participants and the context in which they were implemented. Table 2 summarises the core information for the twenty-six (N=26) interventions. More detailed information on the background of the participants and the context of the interventions follows.

*Table 2: Participants and implementation context of Year 2 school interventions*

Intervention Code	#Students	#Groups	#Boys/ #Girls/ #Other	Age	Total duration	#Sessions
NKUA0201	22	8	12/10	14-15	8	2
NKUA0202	44	20	22/22	12-13	8	8
NKUA0203	30	10	17/13	12-13	10	5

NKUA0204	21	5	8/13	13-14	9	5
NKUA0205	14	4	12/2	16-17	12	6
NKUA0206	14	4	9/5	11-12	8	2
NKUA0207	5	2	2/3	15-16	8	4
NKUA0208	13	4	9/4	13-14	8	2
UGHENT0201	60	12	30/30	16-18	8	2
UGHENT0202	11	5	7/4	12-14	5	5
UGHENT0203	18	4	11/7	17-18	16	8
UGHENT0204	13	4	6/7	17-20	8	4
OU0201	28	8	16/12	12-14	6	6
OU0202	8	3	5/3	11-13	6	6
NTNU0201	20	9	11/9	11-12	6	2
NTNU0202	19	9	8/11	11-12	6	2
NTNU0203	21	9	11/9/1	11-12	6	2
NTNU0204	47	22	25/18	12-13	7	3
NTNU0205	51	19	21/28/2	13-14	6	2
NTNU0206	26	12	11/15	11-12	6	2
NTNU0207	18	8	9/9	12-13	6	2
NTNU0208	12	6	9/3	14-15	6	2
NTNU0209	11	5	5/4/2	13-14	6	2
LNU0201	76	19	33/43	14-15	9	4
TCD0201	18	6	12/6	15-16	7	7
TCD0202	19	6	11/8	15-16	7	7
<b>TOTAL</b>	<b>639</b>					

## 4.2 Participants

In Year 2 a total of 639 students aged from 11 to 20 Years old participated in the interventions. Below we provide information regarding students' previous experience with DT and the project's technologies, and students' additional needs.

### **Students' previous experience with DT**

Students that participated in fourteen (14) interventions had no experience with DT while in ten (10) interventions students had some previous experience with DT methodology.

- The students that participated in NKUA0203 were familiar with the DT phases as they followed the same steps during their robotics projects.
- In UGHENT0204 students had one prior interaction with the methodology during one of their school assignments.
- In NTNU0201, NTNU0202 and NTNU0203 the participating students had experience working on design projects (IB model of design) since Grade 6 (e.g., two lessons every week) and coding projects since Grade 1 (e.g., Scratch, Lego League, Beebot, Micro Bit).
- In NTNU0204 students had been engaged in a project to design and create a house/accommodation without the use of technology.
- In NTNU0206 students had some experience in game creation (e.g., Scratch, MicroBit, Code.org, Codecombat etc.) following a similar approach of DT since Grade 5. The frequency of this kind of project is about one per school semester.
- The students that participated in NTNU0207, NTNU0208 and NTNU0209 had experiences working on design subjects since Grade 7 and art subjects since Grade 1.
- The students that participated in LNU0201 were not familiar with the DT phases.

### **Students' previous experience with project's technologies**

In most of the interventions, twenty-two (N=22) students did not have any previous experience with project technologies while in two (N=2) interventions (NKUA0201, NKUA0207) students had previous experience with MaLT2 but not with nQuire. Regarding their experience with educational technologies in general students in six (N=6) interventions (NKUA0203, NKUA0206, NTNU0201, NTNU0202, NTNU0203, NTNU0206) have been taught educational robotics, while in fourteen (N=14) interventions (UGHENT0203, NKUA0201, NKUA0205, NKUA0206, NKUA0207, NKUA0208, NTNU0201, NTNU0202, NTNU0203, NTNU0204, NTNU0206, NTNU0207, NTNU0208, NTNU0209) students have been involved in coding activities in the past.

Students in LNU0201 did not have any experience with project technologies.

### Students' Additional needs

Regarding special needs and characteristics of the students, ten (N=10) interventions included students with additional needs.

- Many of the students in NKUA0205 have behavioural issues and learning difficulties as they come from a low socioeconomic background and struggle with family and financial issues. Students in this school have low participation and motivation for learning. Incidents of criminal behaviour have also taken place in the school and teachers struggle with students' participation at school.
- Two (N=2) students that participated in UGHENT0204 have been diagnosed with autism spectrum syndrome. One (N=1) student follows a part time school trajectory due to learning difficulties.
- In OU0201 and OU0202 at least five (N=5) students have ASD and moderate learning difficulties.
- In NTNU0202 one student (N=1) is diagnosed with autism.
- In NTNU0204 some students have additional needs.
- In NTNU0205 two (N=2) students follow an individual education plan (individuell opplæringsplan in Norwegian) which means they receive some special education each week. Four (N=4) of the students struggle with reading/writing and need more time than other students to understand the basic concepts in most subjects. These students had no problem doing the activities but may not have learnt as much as some of the other students. These students received extra support to make sure they understood the tasks.
- In NTNU0207 at least three (N=3) students followed different educational plans (e.g., English, Norwegian, and sometimes Maths) and one student was diagnosed with ADHD.
- In NTNU0208 one (N=1) student has depression and follows a different school program and one student is diagnosed with ADHD.
- Two (N=2) students that participated in NTNU0209 receive extra help as they are at a lower level compared with others (i.e., lower learners).
- In LNU0201 some students receive extra help and additional needs.

#### 4.2.1 Implementation Context

The interventions were implemented in eighteen (N=18) schools in six (N=6) EU countries (Greece, Norway, UK, Belgium, Ireland, Sweden) during the spring semester of the School Year 2023-2024, March to June 2024:

- Fourteen (N=14) were secondary schools, three (N=3) were middle schools and one (N=1) a primary school.
- Fourteen (N=14) were public schools and four (4) were private schools.

- Eleven (N=11) of the schools were in urban areas, six (N=6) schools were in the suburbs, and one (N=1) in a rural area.
- The duration of each intervention ranged from 5 to 12 hours.
- Four (N=4) interventions were run by one teacher alone, ten (N=10) interventions were run by one teacher and one researcher supporting the process, two (N=2) interventions were run by one teacher and supported by two researchers, in nine (N=9) the teacher was supported by three researchers, and one (N=1) intervention involved three teachers and five researchers.
- Thirty-six (N=36) classes were involved.
- All twenty-six (N=26) interventions were implemented in person, in the school's computer lab or in the classroom.
- 23 interventions were integrated into the school program and were implemented during main class hours, and 3 were implemented as part of an after-school program. All interventions involved activities that could be implemented in the context of the curricular activities.

At specific partner/country level:

- NKUA implemented eight (N=8) interventions in seven (N=7) public schools in Greece. Seven (N=7) of them were implemented in secondary schools located in urban areas while one of them was implemented in a primary school which is in a rural area outside Athens. All schools were state-funded. Three (N=3) of the secondary Greek schools were Model Schools and one (N=1) experimental. These schools offer additional opportunities to students such as participation in cultural programs and innovative actions and participation in research programs through collaboration with universities and other research institutions. Students are admitted to model schools through exams. One (N=1) of the schools was a Vocational High School where the curriculum aims to connect general education with technical and professional knowledge, providing the opportunity to students to acquire a high level of general education and comprehensive professional knowledge and skills for access to the job market and professional advancement. Students in six (N=6) of the schools come from a middle socioeconomic background. In the primary school and the Vocational High School, the socioeconomic status is considered as being low.
- UGent implemented four (N=4) interventions in three (N=3) public schools located in urban areas. All three (N=3) are state-funded, the admissions are non-selective and students came from a mixed socioeconomic background. Two interventions were implemented in a school with many diverse nationalities.
- OU implemented two (N=2) interventions in one (N=1) public secondary school located in a suburban area. The school is state-funded and the admissions are

nonselective. The socioeconomic status of the school pupils is low with a large percentage being on free meal programs.

- NTNU implemented nine (N=9) interventions in five (N=5) schools. Three (N=3) were middle schools while two (N=2) were secondary schools. Two (N=2) were private and three (N=3) were public state funded schools, while three (N=3) require fee paying in addition to the state funding. The admissions in all NTNU schools were non-selective. One (N=1) of the schools has a mixed variety of all socio-economic backgrounds based on the general impression stated in the application forms regarding their parents’ educational background and occupation. Parents are immigrants from Europe, Asia, Africa, and America. There are a few refugee students in this school. In the other four (N=4) schools the socioeconomic status of the students is middle to upper.
- LNU implemented one (N=1) intervention in a state-funded school (N=1) located in an urban area. The intervention spanned three weeks. Students were divided into three classes: Yellow, Orange, and Red. Each class participated in seven sessions, totalling 21 led by three teachers. Each session lasted approximately 1 hour and 15 minutes.
- TCD implemented two (N=2) interventions in a co-educational, culturally and religiously diverse private secondary school located in a suburban area. The school is fee paying and the students broadly come from a middle-class socioeconomic background.

### 4.3 Design Thinking Activities

#### 4.3.1 Overview of the DT activities

In the following table, we provide an overview of the DT activities that were implemented in Cycle 2 of the school implementations. The full Activity Plans are presented in the Appendices A-S a supplementary document related to this deliverable.

*Table 3: Overview of Year 2 DT Activity Plans co-designed by teachers and researchers for school interventions*

No	Interv. code	Tech	DT issue/theme	Learning Domains	Final students’ constructions
1	NKUA0201	MaLT2	Jewellery and more	Mathematics	Small objects, printed on a 3D printer that many people will like and use
2	NKUA0202	ChoiCo	Educational games on map	Computer Science Programming	Digital game in ChoiCo as a serious game built on google maps and enhanced with

					information and parameters that students embed into the ChoiCo game
3	NKUA0203	Sorbet	Cyber Security with Sorbet	Computer Science	Sorting games related to cyber security, specifically addressing FireWall, Strong Passwords and Phishing
4	NKUA0204	ChoiCo	Travelling with ChoiCo	Geography	ChoiCo games for people with specific needs who want to travel abroad like families with young children
5	NKUA0205	ChoiCo	Entrepreneurship with ChoiCo	Entrepreneurship	ChoiCo games that simulate the practice of entrepreneurs
6	NKUA0206	GearsBot	Cleaning Robot for the Shores	Mathematics	Virtual robotics simulations where robots are programmed to clean polluted shores
7	NKUA0207	MaLT2	Personalised items	Mathematics	Small 3D-objects designed by using a solid, such as a quadrilateral or a cylinder that will be printed
8	NKUA0208	MaLT2	Make Puzzles	Mathematics	Puzzles, printed on a 3d printer that many people would like to play with
9	UGHENT0201	ChoiCo	SDG 11- Sustainable city	Society & STEM	ChoiCo games about sustainable cities
10	UGHENT0202	ChoiCo	The world of Music & Sound	Physics Computer Science	A combat ChoiCo game about music (waves, frequencies...)
11	UGHENT0203	ChoiCo	SDG 11- Sustainable clothing & sustainable food & sustainable	Economics Society & STEM	ChoiCo simulations with choices about their concrete problem statement with a set of criteria

			school management		
12	UGHENT0204	ChoiCo	Ecology in the city	Biotechnology	ChoiCo games about the city of Dendermonde, where there is a problem with mobility, but more streets mean loss of green zones
13	OU0201	SorBET	Recycling	Chemistry	Sorting games about recycling
14	OU0202	SorBET	Types of Forces	Mathematics Physics	SorBET games to educate people on the type of forces and whether a force is balanced or unbalanced
15	NTNU0201 NTNU0202 NTNU0203	GearsBot	Access matters	Social studies Programming	The outcome of the activity is a layout plan (blueprint) of a school accessible for all
16	NTNU0204	GearsBot	Become a master of Recycling	Mathematics Programming	Block-coding solution that successfully recycles garbage items
17	NTNU0205 NTNU0206 NTNU0207 NTNU0208 NTNU0209	SorBET	Daily Adventures with AI	Social studies Programming	Sorting games regarding items (namely, a database) that need to be 'fed' to the AI to resolve the protagonist's problems
18	LNU0201	ChoiCo	The Beekeeper's game	Environmental education	ChoiCo games about suitable places where beekeepers can move their hives, considering needs of bees and factors threatening their well-being
20	TCD0201 TCD0202	Open	Solving Fast fashion	Civic, Social & Political Education Computer Science	A game or product, using MaLT2, ChoiCo, or SorBET, that will attempt to solve a fast fashion-related issue

### 4.3.2 Domains, learning outcomes & flow

#### Domains

Year 2 interventions integrated DT with twelve (N=12) scientific domains: Mathematics, Computer Science, Engineering, Programming, Physics, Chemistry, Geography, Entrepreneurship, Economics, Biotechnology, Environmental education and Civic, Social & Political Education (Figure 6). Although there was a variety of domains of activities, Mathematics and Social Studies were the most frequent. Most of the social-scientific issues that the DT projects aimed to address were relevant to environmental education, such as ecology (UGHENT0201, UGHENT0202, UGHENT0203, UGHENT0204 ), recycling (OU0201), coastal pollution (NKUA0206) and beekeeping (LNU0201), sustainability issues related to urban life (UGHENT0201, UGHENT0202, UGHENT0203, UGHENT0204), food, clothing (TCD0201, TCD0202) (e.g., cities, schools); whilst one was related to cybersecurity (NKUA0203) and another to entrepreneurship (NKUA0205).

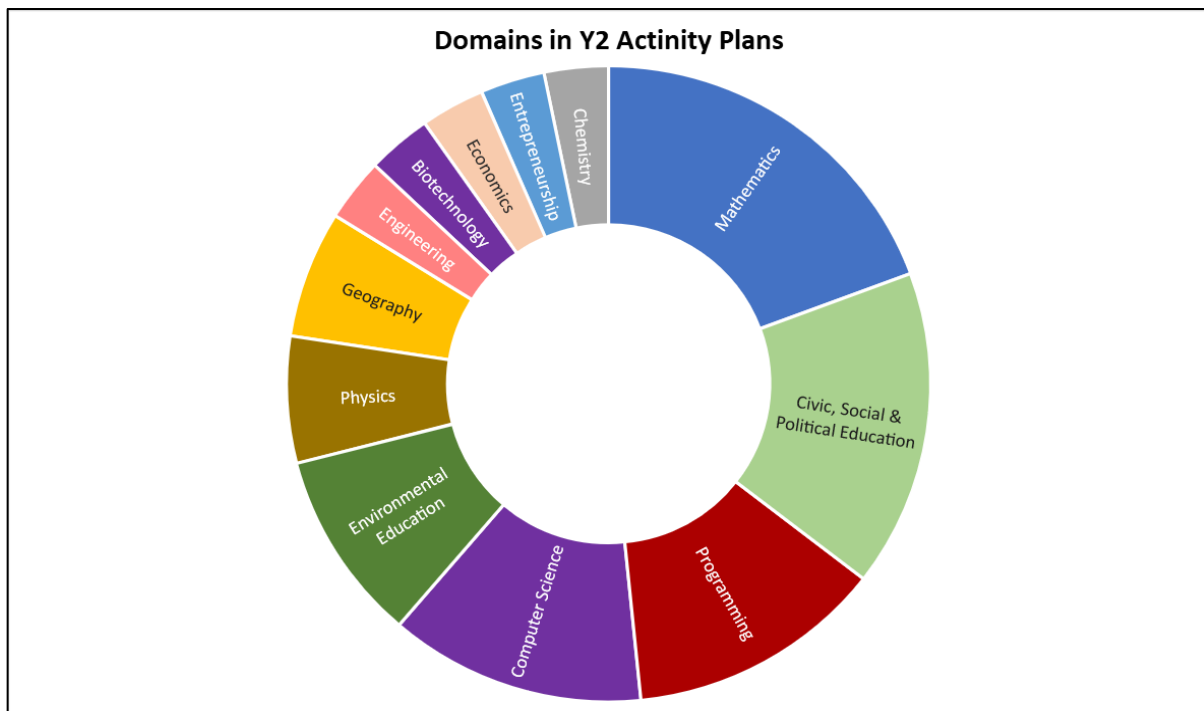


Figure 6: Domains in Year 2 DT Activity Plans

#### Learning Outcomes

During the design of the activities, emphasis was given to the formation of specific learning outcomes with the use of learning objective verbs in order for the teachers to be able to assess them as observable behaviours (see section 5.5 Learning Outcomes). The learning outcomes referred to: a) the learning domain (e.g., Mathematics), b) DT mindset and the use of ET for DT (e.g., Prototyping), and c) 21st-century skills (e.g., Collaboration).

Although the activities were not always directly linked to the respective formal national curriculum, certain concepts and learning outcomes were directly linked to curriculum learning content and objectives. These included, for example, learning outcomes about mathematics (e.g., 2D & 3D shape properties or algebraic functions in NKUA0201, NKUA0207 and NKUA0208), programming (e.g., Boolean operators and conditions in NKUA0203 and NKUA0206), and geography (e.g. recall important landmarks in European cities in NKUA0204).

Regarding the expected learning outcomes about Design Thinking and Innovation with emerging technologies (Figure 7) all the APs (N=19) referred to students’ ability to develop rapid prototypes through iterative design. Most address the user-centric nature of DT methodology as they focus on students’ ability to analyse information and interpret data collected in most cases through the nQuire questionnaires on users’ needs (N=16 out of 19 APs) and to interpret and proceed with reflection and feedback by discussing, deciding on and planning modifications to their artefacts according to the feedback received from their peers (N=16 out of 19 APs). Less mentioned expected learning outcomes were Empathy (N=3), Brainstorm & Critical Thinking (N=3), Ideate (N=2), Define (N=1), Deliver Define (N=1), Experimentation (N=1) and Problem-Solving (N=1).

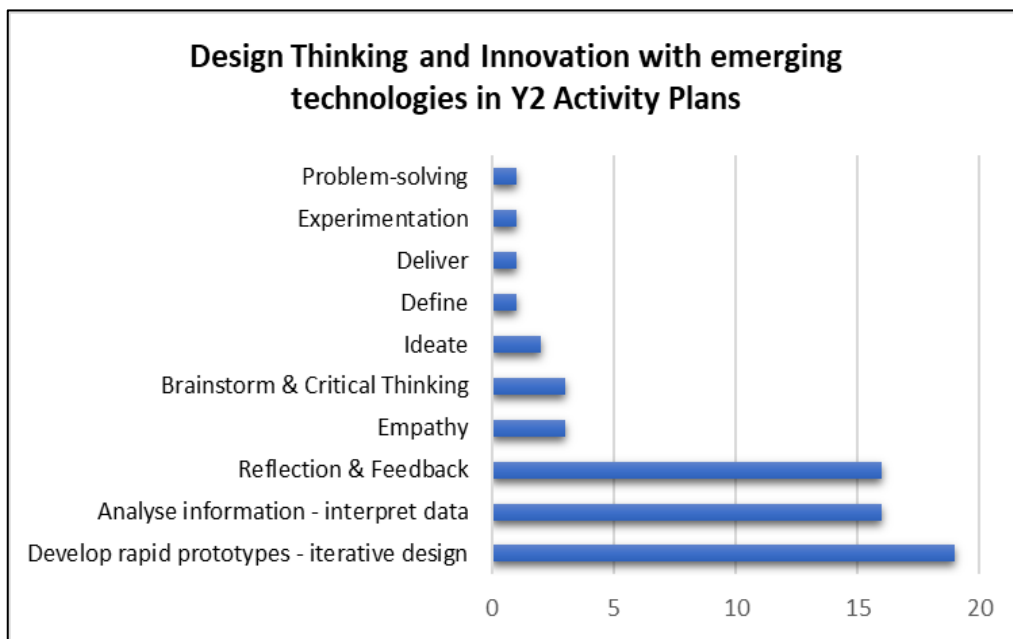


Figure 7: Learning outcomes about Design Thinking and Innovation with emerging technologies in Year 2 APs

Finally, on 21st-century skills (Figure 8), all refer to the learning outcome of the skill of Communication (N=19) followed by the skill of Presentation (N=13 APs out of 19). Other 21st-century skills that were less referred to in the AP of Y2 were Creativity (N=3), Collaboration (N=2), Computational Thinking (N=2), Evaluation (N=2), Digital Literacy (N=1), Critical Thinking (N=1), Time management (N=1), Decision making (N=1) and Reflection (N=1).

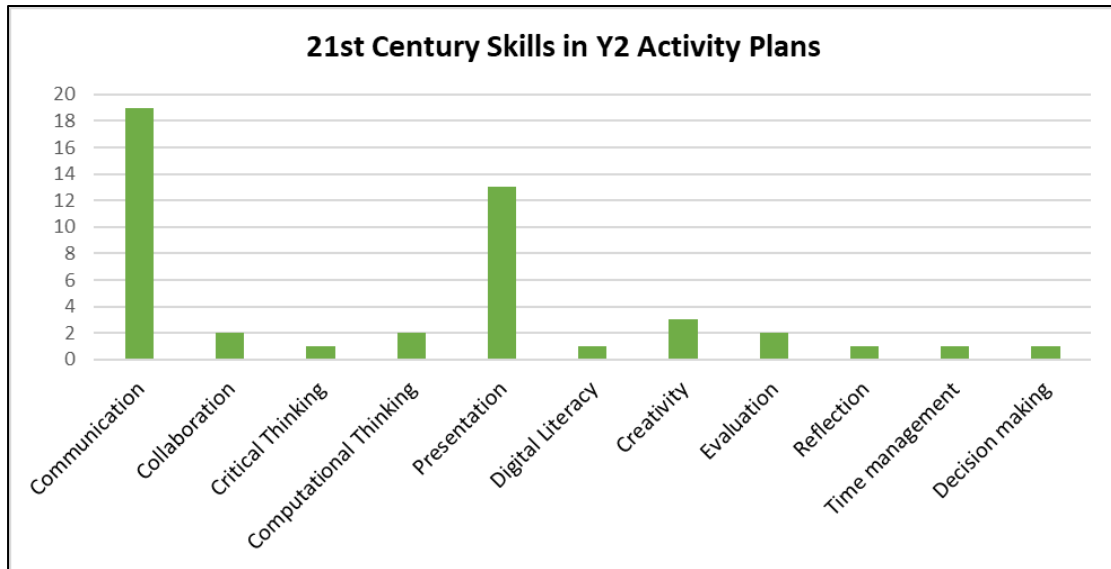


Figure 8: 21st-century skills addressed by Year 2 DT Activity Plans

Reflecting on the charts, (Figure 7, Figure 8) it is interesting to comment on the dualities “Reflection / Reflection & Feedback ” and “Critical Thinking / Brainstorm & Critical Thinking”. Observing the expected learning outcomes about Design Thinking and Innovation with emerging technologies and the 21st-century skills, addressed by Year 2 DT Activity Plans, we can see that the concepts of Reflection and Critical Thinking are mentioned both as DT with ET skills and 21st-century skills by teachers. For example, in the “Fast fashion” AP (TCD0201-02) ‘Reflection’ as a 21st-century skill is noted, whereas in NKUA0204–08, UGHENT03-04, TCD0201-02, OU0201-02, NTNU05-09, LNU0201, the teacher includes ‘Reflecting & Feedback’ together in DT with ET related learning outcomes. As a DT with ET related skill ‘Reflection’ in the second case is directly related to prototyping and feedback as the specific learning outcomes mention: a) evaluating feedback received from peers and reflecting on one’s own work, b) using the feedback received by making decisions and planning modifications to improve their prototypes, and c) providing specific feedback to peers to improve their prototypes. While only one AP (NKUA0203) mentioned ‘Critical Thinking’ as a general 21st-century skill, referring to the students’ abilities to critically decide on the SorBET categories and the objects that deserve to be classified in their game, and the students’ critical interpretation of the nQuire answers, three other APs (UGHENT0201-02-03) mention ‘Critical Thinking’ along with ‘Brainstorming’ as a DT related skill related to the critical evaluation of different options and their consequences.

**Flow**

Figure 9 shows the time distribution across the five DT stages for every intervention and the average duration of each stage across interventions. Eighteen (N=18) APs implemented the five phase Exten.(D.T.)<sup>2</sup> Design Thinking model. UGHENT0203 is not included in the diagram shown in Figure 9 as the teacher implemented a rather modified version of the model (*Empathise & Understand & Define, Ideation, Pre-prototyping, Prototype, Test*), mainly due to

the intervention serving specific curriculum objectives - and so had to be adapted to the methodology proposed by the curriculum of the school for the implementation of such activities.

On average, the “Rapid Prototyping & Iteration” phase stands out from the rest, having an average duration of 2.5 hours. The other phases are almost equal in length, averaging almost 75 minutes. The phase with the longest duration is an NKUA intervention that lasted 4 hours in the ‘Rapid Prototyping & Iteration’ phase. The phase with the shortest duration belongs to NTNU interventions, which lasted 30 minutes and involved ‘Respond & Deliver’.

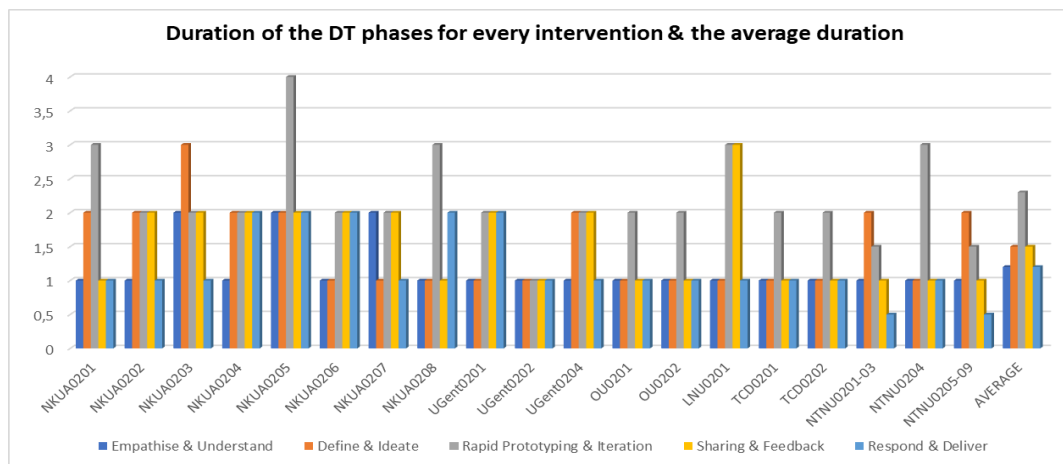


Figure 9: Duration of the five DT phases for every intervention and the average duration of each stage across Year 2 interventions

In Cycle 1 interventions, the focus was primarily on the ‘Develop’ phase. In Year 2, the Exten(D.T.)<sup>2</sup> model, developed for Cycle 2 of the project’s school interventions, achieved a more balanced distribution of time across all DT phases. This approach ensured that students engaged with every aspect of the DT methodology without missing any crucial elements such as feedback. While the ‘Rapid Prototyping and Iteration’ phase still tended to last the longest, sufficient time was allocated to the ‘Sharing and Feedback’ activities. This allowed students to receive and apply valuable feedback from peers, instructors, and external actors, such as family and friends, in their designs highlighting the user-centric nature of the methodology and emphasising the development of skills such as communication, as mentioned above (Learning outcomes). Another notable difference from Year 1 was that more time was allocated for students to present and discuss their work during the last phase. This interactive engagement meant that students not only presented their artefacts but also “responded” to the feedback they received in the previous phase and highlights the emphasis that was given to communication related learning outcomes.

### Iteration Cycles

A notable aspect of Year 2 interventions was the iteration cycles between DT phases. These were mainly related to ideation and feedback activities. Regarding ideation, students were

engaged in processes of defining the issue at hand and form their initial ideas during the first phase of the project. For example, in the activity NKUA0201 “students make a very first, rough description of their idea for construction, either with a drawing, or by finding and showing pictures, or by describing it, or by combining the above ways” during the “Empathise and Understand” phase while the second phase mainly concerned activities with the tools, aiming for the students to get familiar with them.

The second type of iteration cycles in many cases were related to feedback from users outside of the group. While the “Sharing and Feedback” phase follows “Rapid prototyping and Iteration” phase, in many cases students were engaged in sharing their artefacts with external users during the “Rapid prototyping and Iteration” phase. For example, in the cases NKUA0203, NKUA0204 and NKUA0205 students received oral feedback from classmates outside their team while they were developing their prototypes. In NTNU cases (NTNU0201, NTNU0202, NTNU0203, NTNU0204, NTNU0205, NTNU0206, NTNU0207, NTNU0208, NTNU0209) students were engaged in two Cycles of feedback with external users. The first was implemented after the “Define and Ideate” phase and referred to their initial design ideas before starting to develop prototypes. The second was implemented during the “Sharing and Feedback” phase, where students shared their prototypes. This approach gave emphasis on the continuous feedback and refinement, which is a core principle of the DT methodology.

### 4.3.3 Technology use

The design and implementation of Year 2 interventions were based on the use of the ExtenDT2 platform and integrated the extended version of the project's technologies (see D5.4). Figure 10 shows the Exten.(D.T.)<sup>2</sup> technologies used in the Second Cycle of interventions:

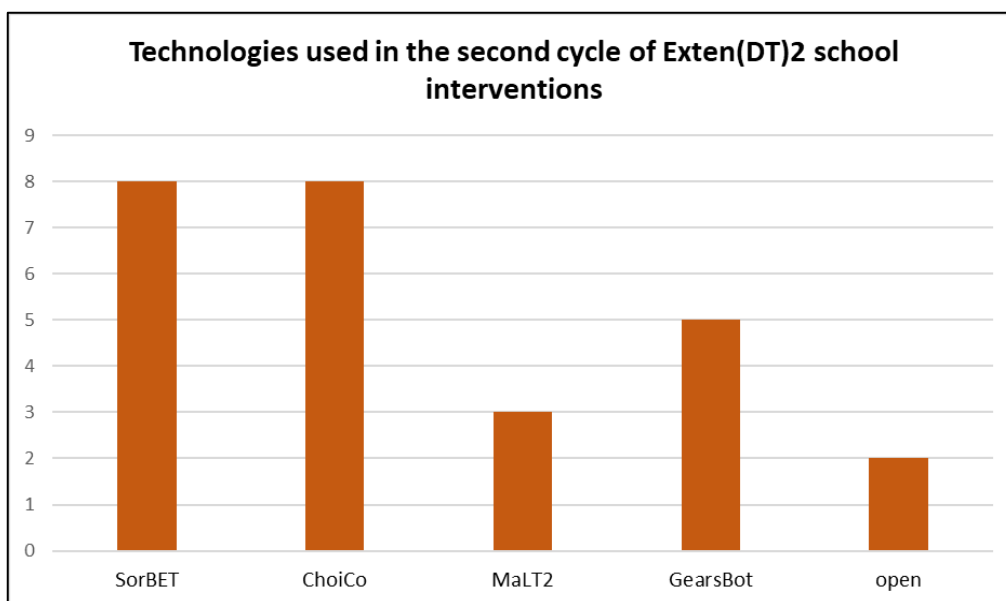


Figure 10: Technologies used during Year 2 interventions

- Eight (8) interventions used SorBET (NKUA0203, OU0201, OU0202, NTNU0205, NTNU0206, NTNU0207, NTNU0208, NTNU0209).
- Eight (8) interventions used the ChoiCo (NKUA0202, NKUA0204, NKUA0205, UGHENT0201, UGHENT0202, UGHENT0203, UGHENT0204, LNU0201).
- Three (3) used the MaLT2 tool (NKUA0201, NKUA0207, NKUA0208).
- Five (5) used a virtual robotics software, GearsBot (NKUA0206, NTNU0201, NTNU0202, NTNU0203, NTNU0204).
- In two (2) interventions (TCD0201, TCD0202) students could choose themselves the tool they would use.

Figure 11 below shows the number of domains that each tool has been associated with. The SorBET tool was associated with seven (N=7) emerging domains, i.e., Computer Science, Chemistry, Mathematics, Physics, Social Studies, Programming and Civic, Social & Political Education. ChoiCo related to the domains (N=10) of Computer Science, Geography, Programming, Entrepreneurship, Mathematics, Physics, Economics, Biotechnology, Environmental Education and Civic, Social & Political Education. MaLT2 was used in activities focusing on three (N=3) domains, Mathematics, Computer Science and Civic, Social & Political Education. Finally, the Virtual Robotics platform was related to Mathematics, Engineering, Programming and Social Studies domains (N=4).

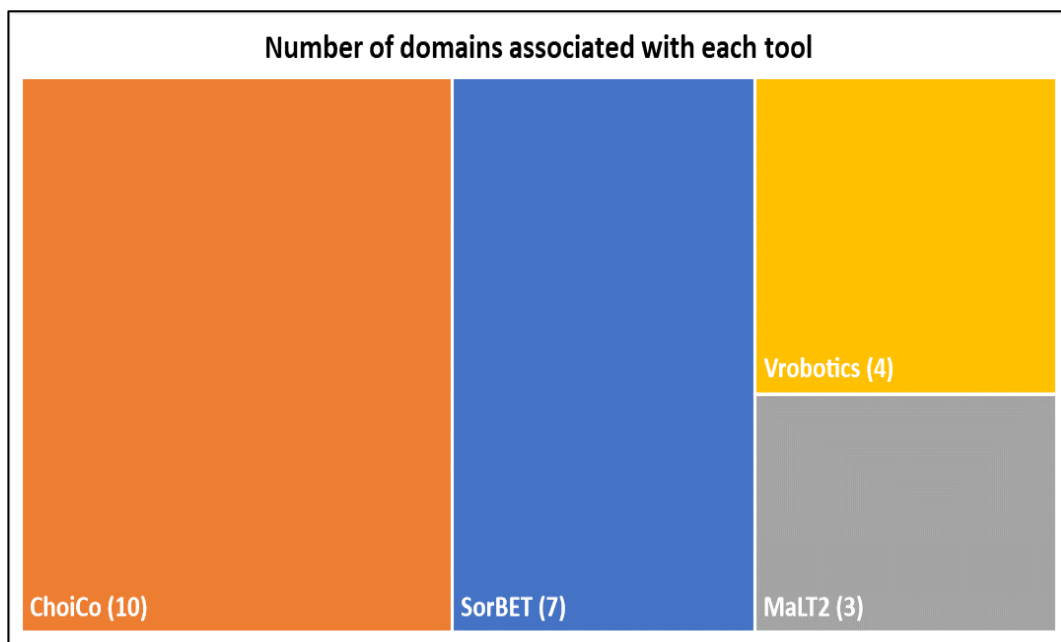


Figure 11: Number of domains associated with each tool in Year 2 Activity Plans

In twenty-one (N=21) interventions students used the nQuire platform to create surveys for their users in the form of missions. While nQuire was initially meant to be integrated in DT projects as a tool to empathise with the target audience, in Year 2, in thirteen (N=13) interventions students used nQuire as a tool to reach the audience during the “Sharing and Feedback” phase, where they shared the link of their artefact extracted by the ExtenDT2

platform with external users and asked for feedback. Eight (N=8) interventions integrated the tool into the “Empathise & Understand” phase as a tool to empathise with the target audience.

A common element in most of the activity plans was the integration of introductory activities with technology during the first phase “Empathise and Understand”. In many cases teachers chose to introduce students to the tool they were going to use during the project, creating activities in the ExtenDT2 platform with already existing artefacts. In NKUA0201, NKUA0207 and NKUA0208 students were introduced to MaLT2 using ready-made examples of Logo procedures which designed 2D and 3D shapes. In NKUA0202, NKUA0204 and NKUA0205 students played existing ChoiCo games to get familiar with ChoiCo games rationale while in NKUA0203 and OU0202 students navigated the SorBET environment playing already existing games to get to know its functionalities.

Noteworthy was the TCD interventions where teachers implemented an additional, “Sandbox” phase (Experimentation Day) during which students experiment with each technology (MaLT2, ChoiCo, SorBET) for 15 minutes using already existing or ‘half-baked’ games and basic codes (for MaLT2). This phase aimed to encourage students’ creativity and decision-making.

#### 4.3.4 Teaching methods & materials

##### Teaching methods & Orchestration

The focus on orchestrating student interactions and improving collaboration through DT projects was evident in all interventions. The grouping criteria that emerged from the APs were: a) students’ preferences, b) mixed school performance, and c) complementarity of skills related to DT as well as the use of technologies. In most activity plans, the criteria for grouping formation were random or based on students’ preferences. For instance, in three of the NTNU interventions and in all of the NKUA (except one based on mixed school performance), TCD, LNU and OU interventions, the main criteria for grouping was students' personal preferences. In one case designed by NTNU, the groups were formed randomly based on the students’ seats in the classroom. In another NTNU case and in two cases from UGHENT, the groups were formed based on the teachers’ knowledge of their students. For example, as reported, each group was planned so as to have one individual with strengths in programming or computational thinking, one who could act as an administrator, one with strong communication skills and one adept with creative thinking.

Regarding students’ roles in the group the majority of the APs did not define them a priori, so the roles that emerged during the activities were defined and distributed by the students. Only three activities, two from OU (, OU0201, OU0202) and the one from UGHENT (0201), had predefined roles for the students within their group, where students were expected to play the distinct roles of *team leader - research lead - game designer - administrator* and,

*game designer - tester of the game - reporter - graphic responsible* respectively. In OU interventions the role distribution was facilitated by a PowerPoint slide describing the tasks and responsibilities of each individual in the group (Figure 24).

Finally, regarding the role of the teacher, only in the four cases of UGHENT has it been reported that the teacher acted as *a coach*. In all the other interventions the teacher’s role was to facilitate, observe, monitor and guide the intervention or to intervene when their support was needed; when students encountered a technical problem with the technology or needed to discuss whether their ideas were feasible (Figure 12, Figure 13).



Figure 12: Teacher as a facilitator in class - NKUA0201



Figure 13: Students working on their digital model in MaLT2, with the teacher intervening to give students ‘food for thought’ about a mathematical property in their geometric figure - NKUA0207

All interventions focused on promoting collaboration and discussions among students (Figure 14, Figure 15, Figure 16), brainstorming (Figure 17), and embedded group activities like giving feedback to peers (Figure 18, Figure 19).

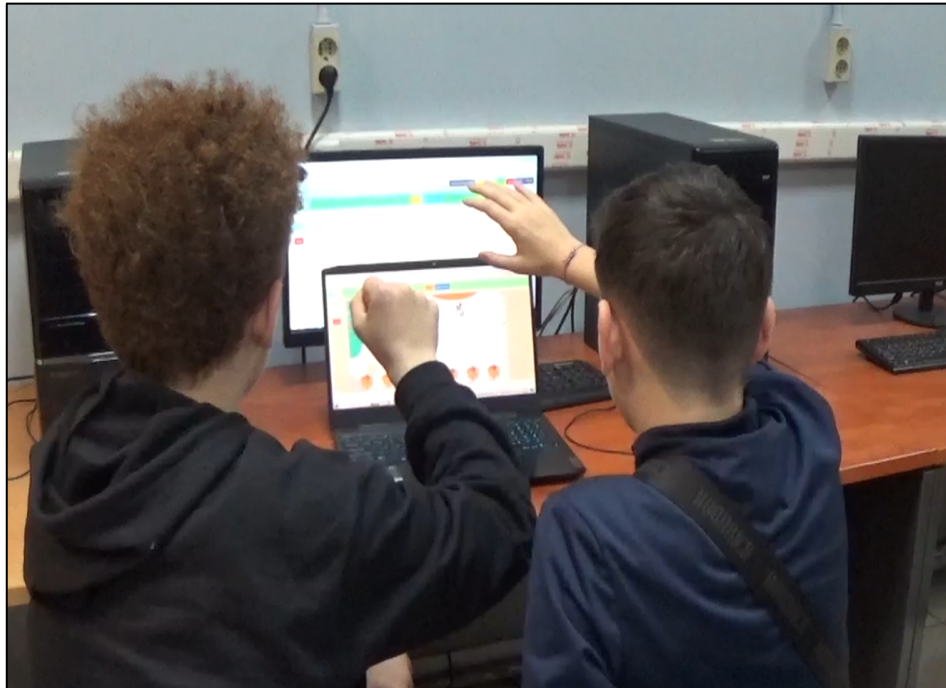


Figure 14: Students working together to test their SorBET game - NKUA0203



Figure 15: Students working collaboratively in group on their ChoiCo game - NKUA0204

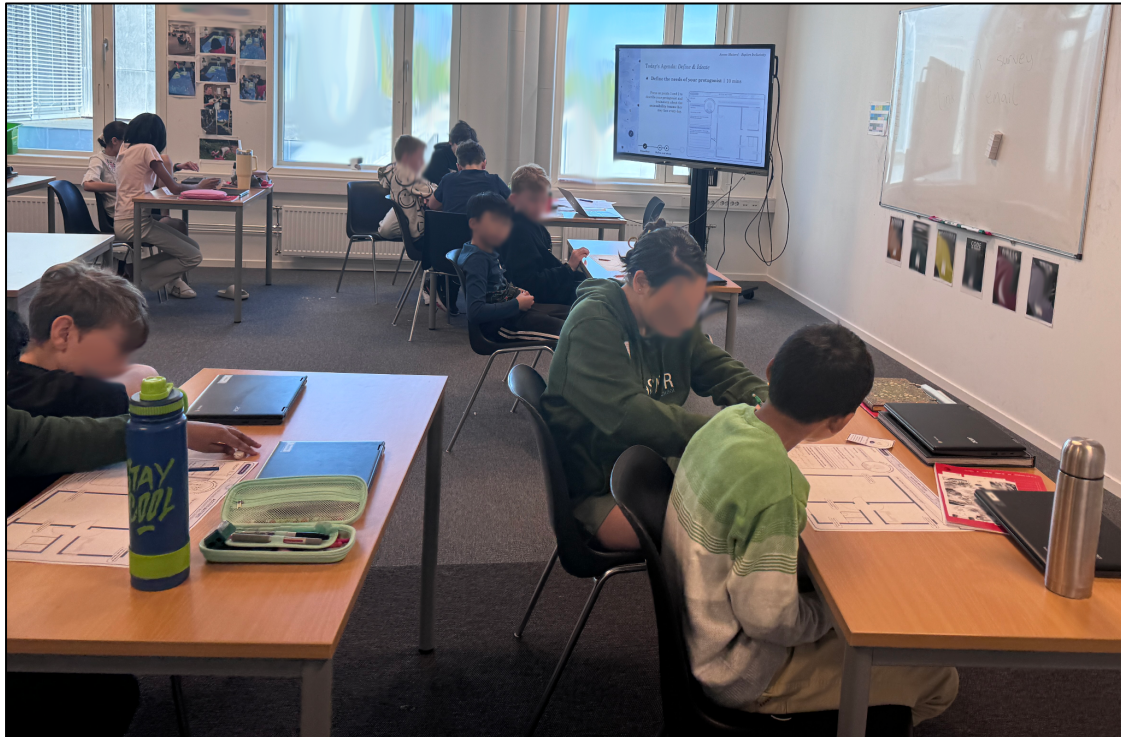


Figure 16: Students working in groups on their simulation in GearsBot - NTNU0201



Figure 17: Students working in groups during brainstorming activities - UGHENT0201



Figure 18: Students during the “Respond & Deliver” presenting their ChoiCo game on entrepreneurship to their peers & teacher acting as observer - NKUA0205



Figure 19: One group gives verbal feedback to another group on their SorBET game and students take notes - NKUA0203

## Supporting materials

To support students' engagement with digital technology, teachers provided them with support resources that included:

- Lists of programming commands for the MaLT2 and the ChoiCo environment
- 1-minute videos and analytical video tutorials for the use of the technologies (Figure 20, Figure 21, Figure 22)
- Manuals and quick guides for SorBET, ChoiCo, MaLT2 and GearsBot (Figure 23)
- Presentations (Figure 24)
- Worksheets (Figure 25, Figure 26, Figure 27)
- Self-assessment rubrics (Figure 28)
- Brainstorming and storyboard cards (Figure 29, Figure 30)
- Feedback questionnaires created by the teacher (Figure 31)
- Slide that describes the specific roles of in the group (Figure 32)
- Existing digital artefacts (i.e., games in ChoiCo, SorBET and 2D & 3D MaLT2 models) (Figure 33, Figure 34, Figure 35, Figure 36, Figure 37)



Figure 20: A screenshot from 1' video for ChoiCo (introduction)



Figure 21: A screenshot from 1' video for SorBET (how to modify speed & density)

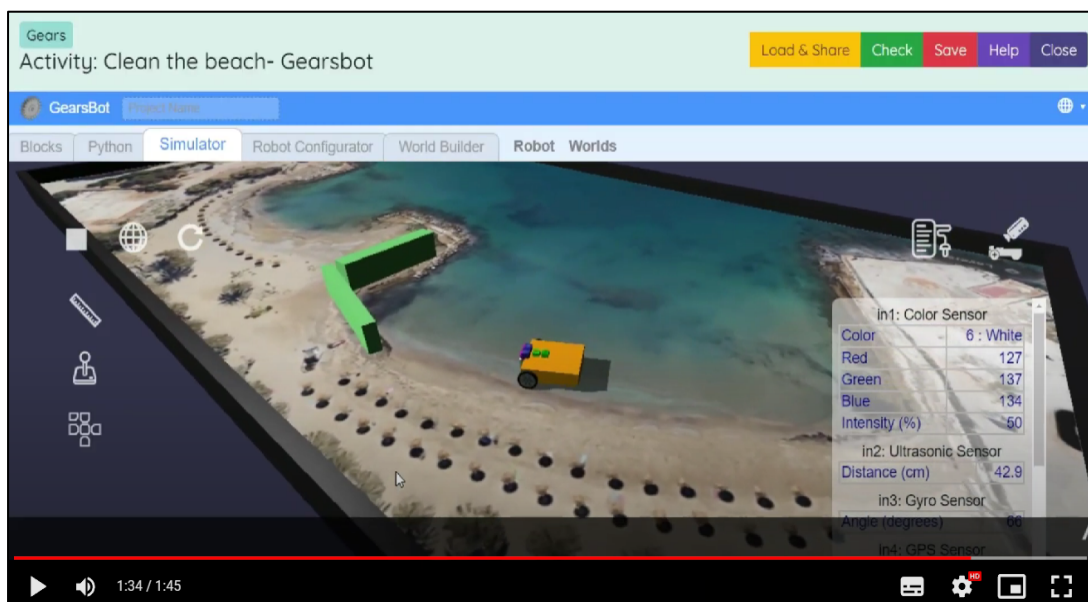


Figure 22: A screenshot from video tutorial used for “Cleaning Robot for the Shores” Activity Plan

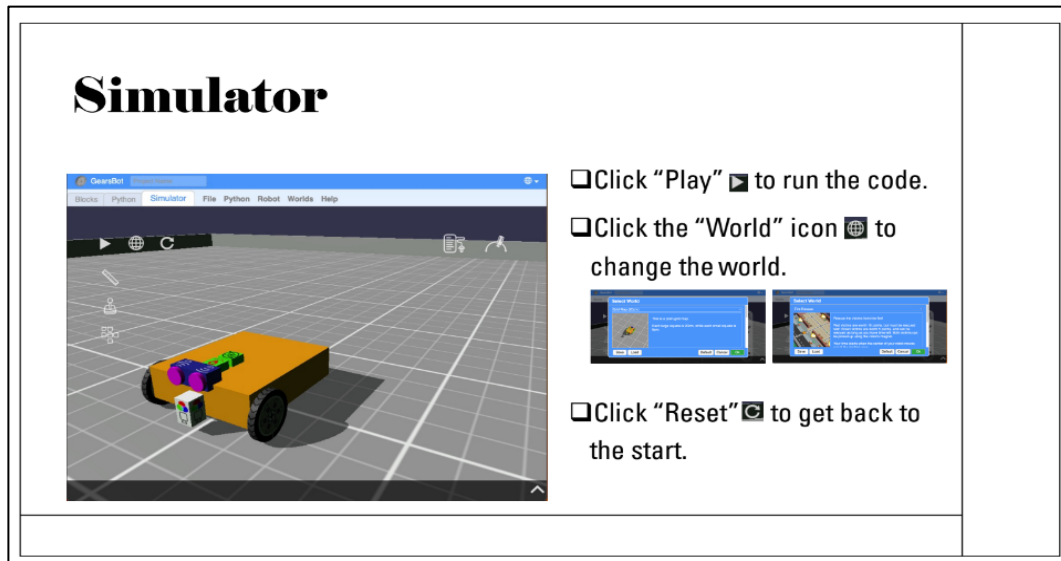


Figure 23: Figure 23: A screenshot from the GearsBot manual

In some cases, to support the students' work during certain DT phases, additional supporting material was designed by the teacher, such as slide presentations and printed worksheets. For example, in the case of the “Cybersecurity” activity, the teacher prepared a slide presentation to inform students about the DT process (description of the five phases) they would follow to create their final SorBET game (Figure 24). Other examples are the cases of TCD where students were given worksheets prepared by the teacher to facilitate the “Define & Ideate” & “Feedback” phases (Figure 25, Figure26) and of UGHENT where teachers also prepared rubrics for students’ assessment after the “Empathise & Understand” phase and for peer review for the “Feedback” phase (Figures 27, Figure 28).

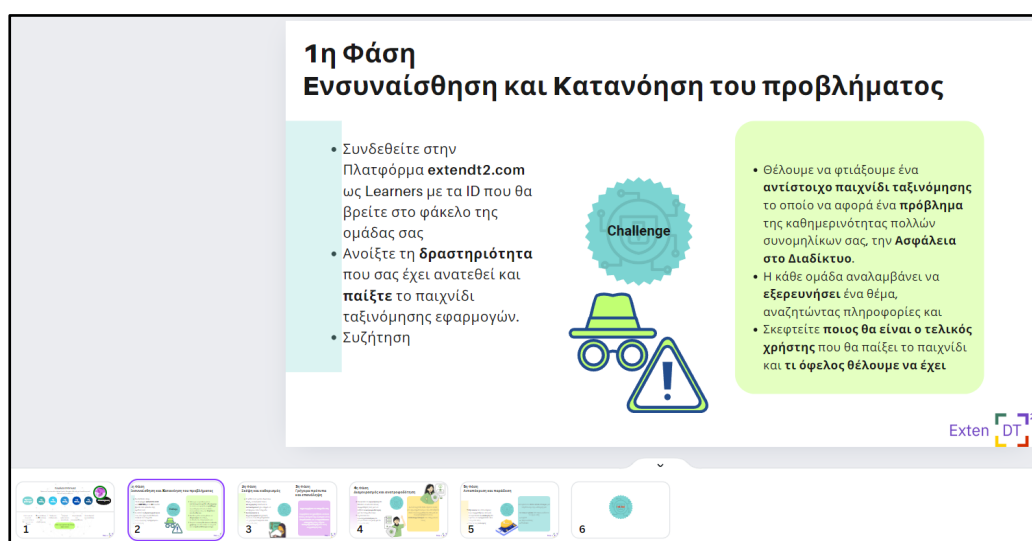


Figure 24: A slide presentation created by the teacher at the 1st phase of the DT project “Cybersecurity” explaining the methodology and the steps the students have to follow to create their final game. The slide depicted describes what students will do during the first phase of the project - NKUA0203

1. Identify 2 issues within our community based on the survey results

2. Select 1 issue your group will focus on and use it to create a "How Might We" question

How Might We + Intended Action  
(as an action verb) + For + Potential User  
(as the subject) + So That + Desired Outcome

**For example:**

• How might we **provide healthier meals** for **teenagers** so that **they stay away from junk food**?

---



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3. On the back of this paper, brainstorm solutions with any of the 3 technologies from last week to answer your "How Might We" question

4. Which technology did your group choose? Why?

5. How does that technology help to address your solution?

Figure 25: "Define & Ideate" worksheet - TCD0201

**Peer Review Session**

Members of group you are assessing:

Each group gives a 3-minute demonstration of their game and are marked as follows:

	Score (20)
ExtenDT2 game is appropriate for the end-users' needs	/5
ExtenDT2 game works	/5
ExtenDT2 game is appealing to the end-users	/5
Information is well communicated	/5

One suggestion or comment:

---

**Final Workshop for Prototypes**

Think about what changes need to be made to your game and make a plan so it is completed by the end of class

Final steps	Time needed

Figure 26: 'Feedback' worksheet - TCD0201

Namen van de leerlingen die feedback geven? (jullie naam)

---

**Wees tactvol!**

**1. Luister even naar de verwachten van de leerlingen die feedback ontvangen.**

- Wat was het doel van het ontwerp?
- Welke (extra) feedback hebben ze nodig?

**Scores:**

(zeer sterk van toepassing, zeer goed= 5 vs totaal niet het geval, ruim onvoldoende = 0)

1. Begrijp je in een oogopslag de infografic?

Ik vind de boodschap van de infografic **duidelijk**

0 1 2 3 4 5

2. Is het een aantrekkelijk ontwerp (esthetiek, kleur, beeld, lettertype en grootte)?

0 1 2 3 4 5

3. Is het ontwerp geschikt voor de doelgroep van scholieren van 3ASO-6ASO?

0 1 2 3 4 5

4. Heb je iets inhoudelijk bijgeleerd over het onderwerp na het bekijken van het ontwerp?

0 1 2 3 4 5

Figure 27: "Peer feedback" worksheet - UGHENT0203

Rubric empathiefase

Beste leerling,

je mocht zonet informatie over een bepaald onderwerp onderzoeken. Hoe vind jij dat je dat gedaan hebt? Omcirkel de stelling die past bij jou.

Naam:

	Niveau 1	Niveau 2	Niveau 3
<b>Oordeel niet meteen</b>	Ik schrijf alleen ideeën op die ik goed vind.	Ik schrijf ideeën op die ik goed vind en minder goed vind.	Ik schrijf goede en slechte ideeën op zonder te oordelen.
<b>Ga voor kwantiteit</b>	Ik stop snel met het bedenken van nieuwe vragen	Ik stop na een tijdje met het aanvullen van nieuwe vragen.	Ik kan lang doorgaan met het bedenken van nieuwe vragen.
<b>Nieuwe info</b>	Ik ga niet snel aan de slag met nieuwe info.	Ik kan behoorlijk overweg met nieuwe info.	Ik kan heel goed overweg met nieuwe info.

Figure 28: Student self-assessment through a rubric designed by the teacher - UGHENT0201

An interesting way of facilitating brainstorming came from eight (N=8) of nine (N=9) NTNU cases where students had to come up with the “protagonist” of their DT intervention using prompt cards and related worksheets prepared by the teachers (Figure 29, Figure 30).

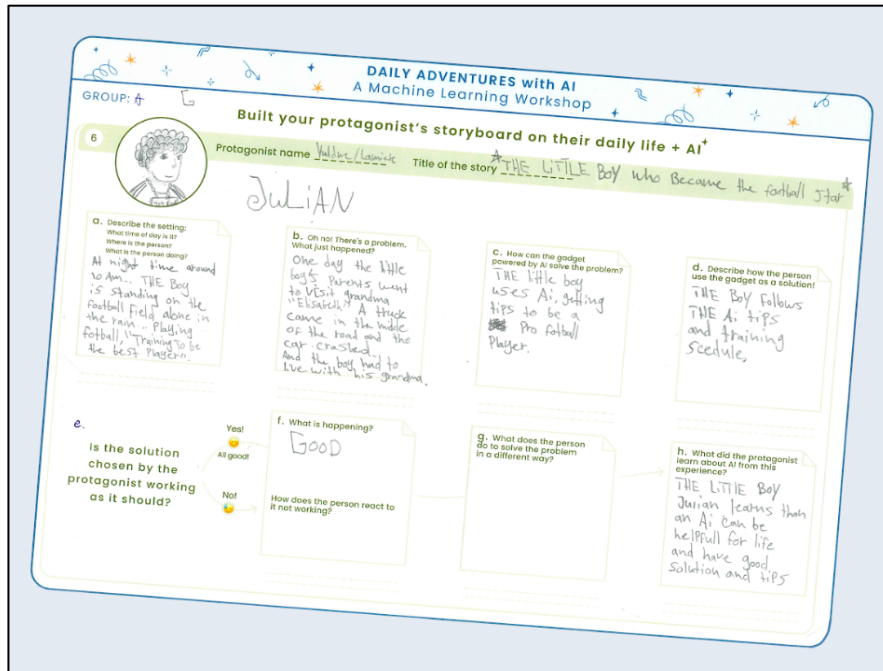


Figure 29: “Storyboard” sheet created by the teacher of “Learning about AI” activity - NTNU0208

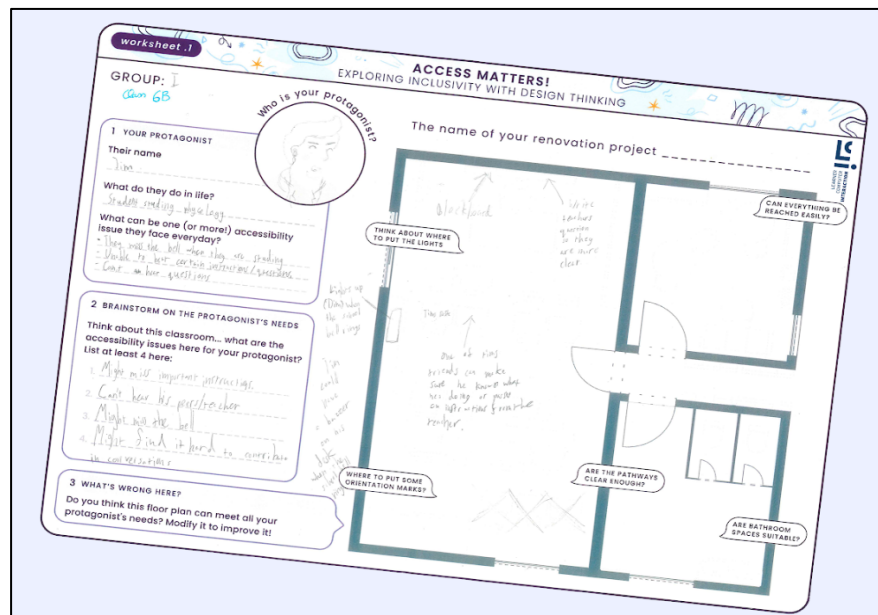


Figure 30: The protagonist worksheet needs to be understood by the students, created by the teacher of the “Access Matters!” activity, before they create their simulation in GearsBot - NTNU0202

Additionally, in the “Learning about AI” cases (NTNU0205-09), teachers created a questionnaire in nQuire for students to give feedback to their peers on their ideas after the “Define & Ideate” phase (Figure 31).

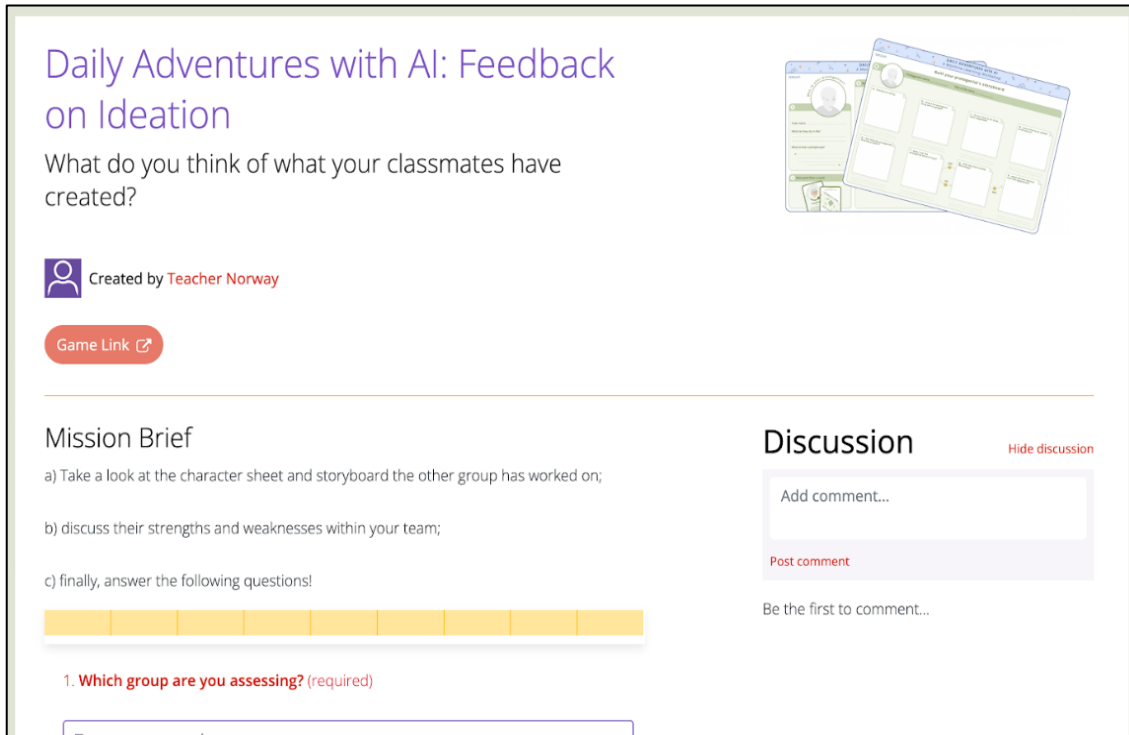


Figure 31: “Feedback questionnaire” in nQuire created by the teacher of “Learning about AI” activity - NTNU0209

In addition, the OU prepared a slide on the specific roles of the group members and a table for each group to fill in to decide on the allocation of roles according to their skills (Figure 32).

As a team, go through the skill set and add each team members initials to how they perceive themselves for each of the following.

Skill	Excellent	Very Good	Good	Average	Poor
Working with others					
Making decisions					
Negotiating roles and responsibilities					
Agreeing realistic goals and planning what needs to be done to achieve them					
Managing time and working to deadlines					
Presenting and communicating information					
Organising and carrying out tasks to meet responsibilities					
Keeping motivated and persuading and influencing other group members					
Coming up with new ideas to solve problems					
Using technology					

**The Roles**

Use your answers from the 'Finding Your Role' table to pick the role that best suits your skills. Pick roles that you think your team needs. These are a few examples:

**Team Leader** - Leads the group to success. Makes decisions, delegates tasks to the rest of the team, sets goals for the team, keeps the team motivated. Creates instructions for the game.

**Designer** - Develop game concepts making changes to the game when feedback is given.

**Admin** - Recording feedback, creating notes in each meeting, ensure feedback is listened to.

Figure 32: Slide that describes the specific roles of in the group - OU0201 & OU0202

In some cases, (NKUA, UGHENT, OU and TCD) teachers used existing online games from the ChoiCo and SorBET platforms to allow students to play and explore them during the “Empathise and Understand” phase, or after it and before moving on to the next phase of the DT process (Figure 33).

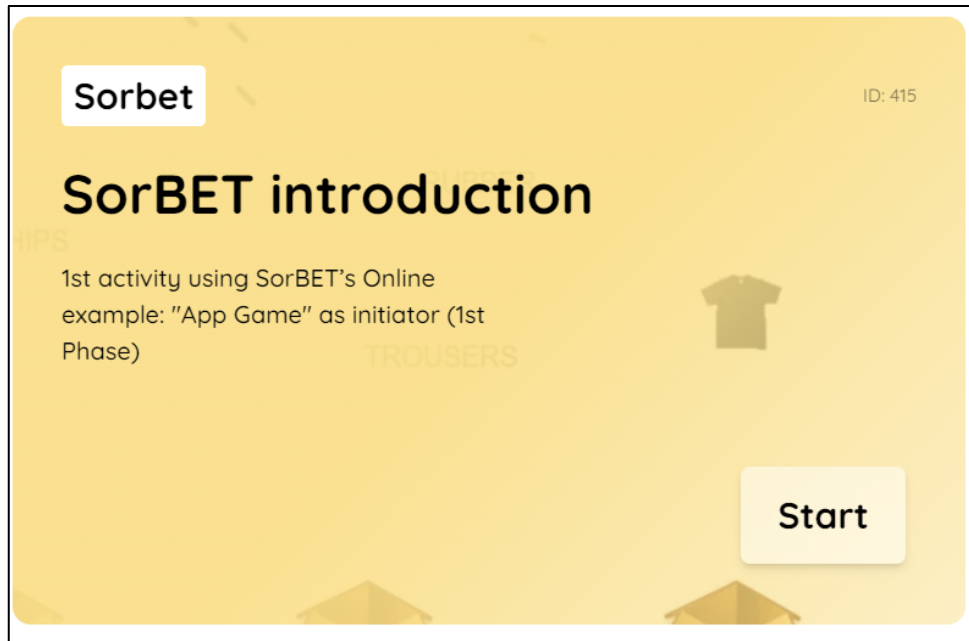


Figure 33: A screenshot of the SorBET activity created by the teacher in the ExtenDT2 platform using the existing online “App game” - NKUA0203

Furthermore, instead of using direct instruction (i.e., introducing loops) to introduce programming concepts or explain the main features of the digital environments, teachers adopted a constructionist approach during the “Empathise & Understand”, “Define & Ideate” and/or “Rapid prototyping & Iteration” phases of the activity plans. One technique used by teachers in eight (N=8) activity plans from NKUA and TCD was the design of 'half-baked' artefacts (Kynigos & Grizioti, 2020). These are artefacts that are not fully developed or contain bugs that require modification and change to support focused learning. Following this approach, teachers designed from scratch or selected existing examples of games or 3D models for their students to use and modify to develop an understanding of the main features of digital environments. By experimenting with these half-baked artefacts, students gained an understanding of how things work.

An example of such an approach is the case of the “Jewellery and more” AP (NKUA0201), where students were given two ‘half-baked’ models designed by their teacher in MaLT2 and were free to explore and tinker with them during the “Define & Ideate” phase. After experimenting with the models, the teacher asked them to modify them as they wished, or to reflect on the way they were constructed by discussing the commands and deconstructing the code that creates these models, always bearing in mind the answers given by their audience. (Figure 34, Figure 35). In addition, the teacher had constructed the codes of the ‘half-baked’ artefacts using the concept of recursion and repetition in to challenge students to think both mathematically and computationally.

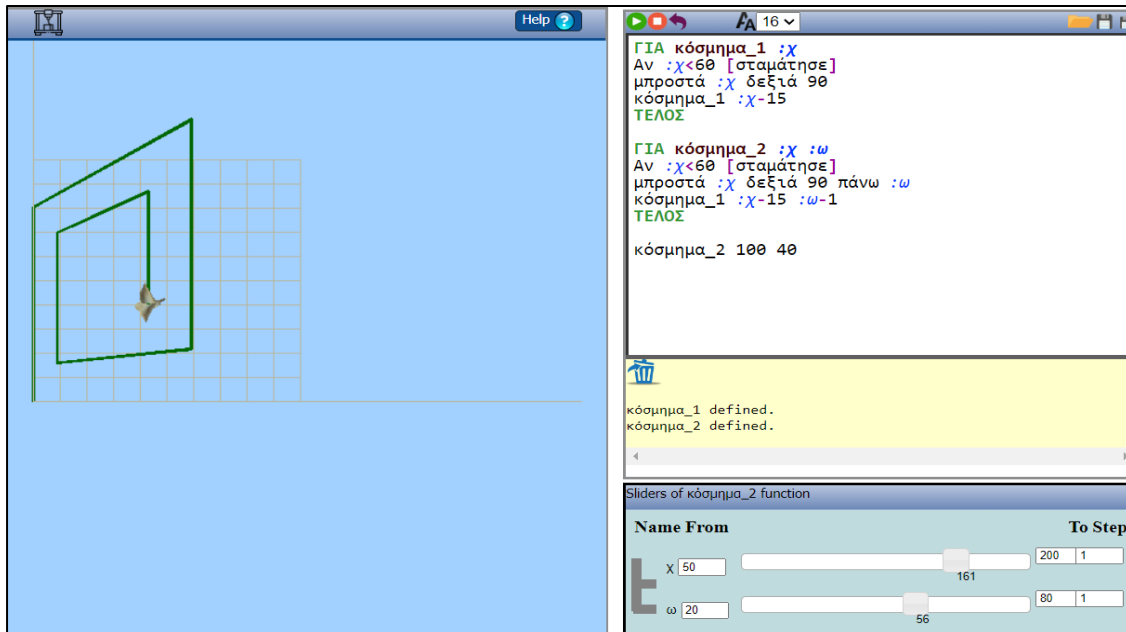


Figure 34: ‘Half-baked’ model 1 designed by the teacher for “Jewellery & more” AP for “Define & Ideate” phase - NKUA0201

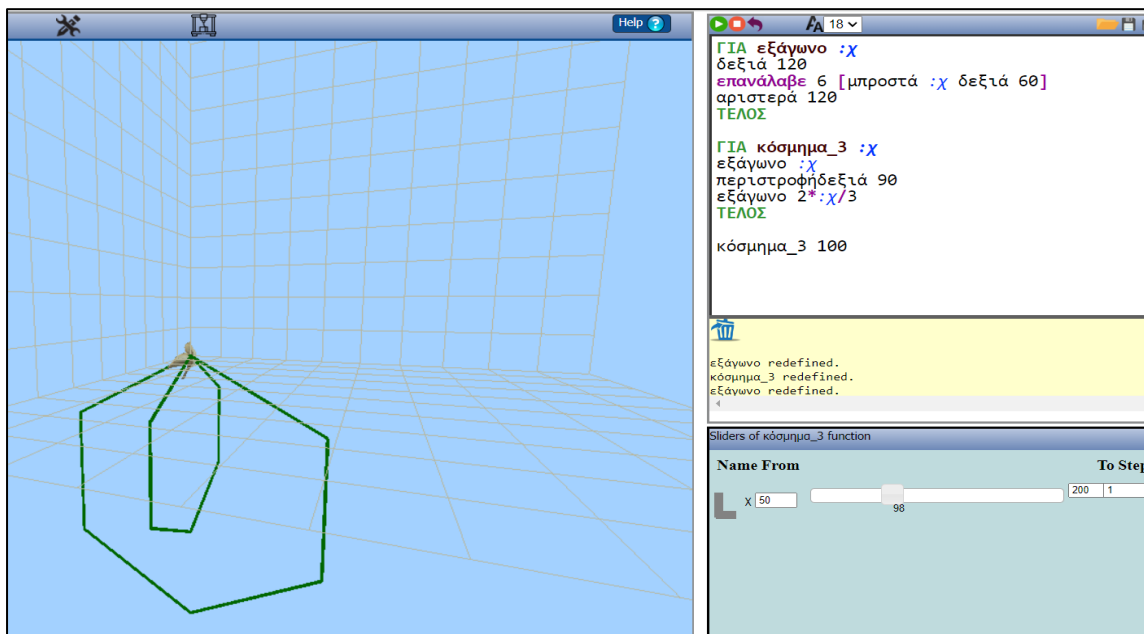


Figure 35: ‘Half-baked’ model 2 designed by the teacher for “Jewellery and more” AP for “Define & Ideate” phase - NKUA0201

Another example is a ChoiCo game co-designed by the teacher and the researcher in “Travelling with ChoiCo” (NKUA0204) related to “Living in Athens”. This uses the Google maps feature embedded in the ChoiCo platform and can be played and modified by the students during the “Empathise & Understand” phase to recognise the rationality and functionalities of ChoiCo games (Figure 36, Figure 37).

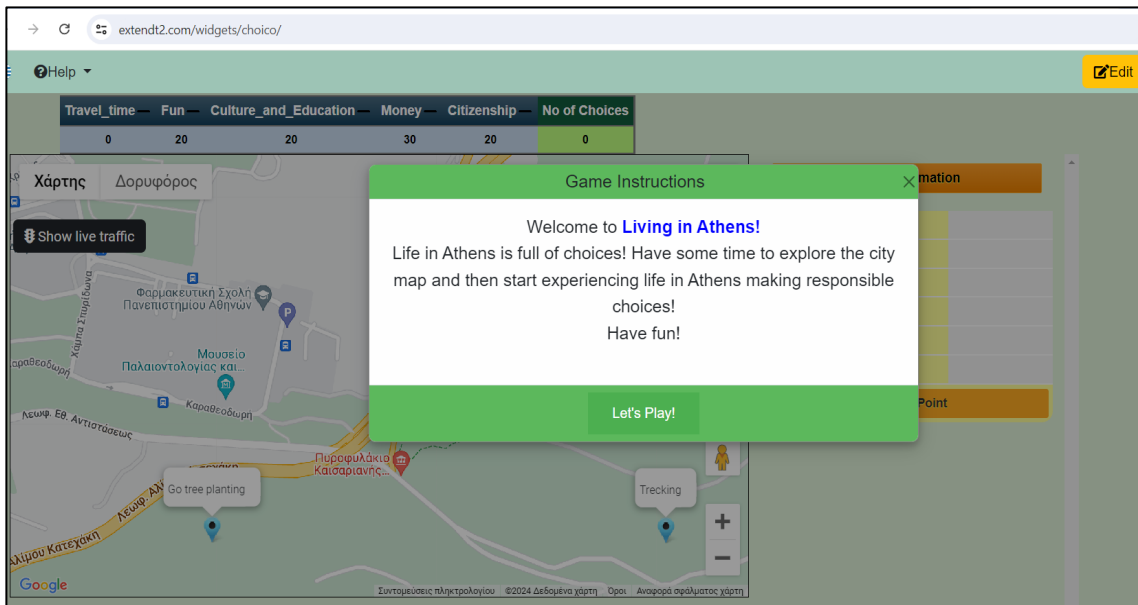


Figure 36: The ChoiCo game “Living in Athens” designed by the teacher and researcher for “Travelling with ChoiCo” activity plan for “Empathise & Understand” phase (Game Instructions) - NKUA0204

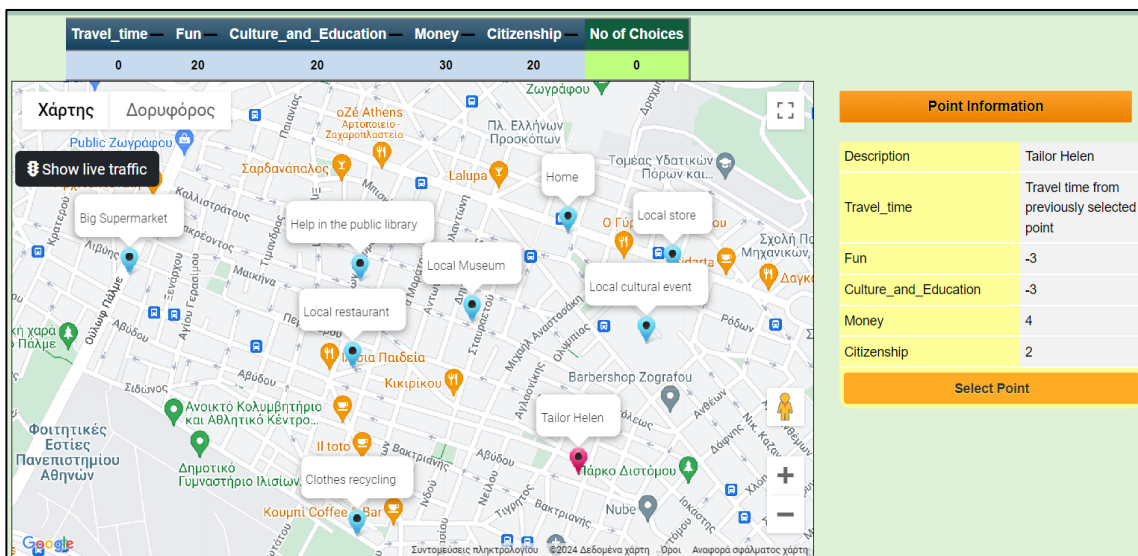


Figure 37: The ChoiCo game “Living in Athens” designed by the teacher and researcher for “Travelling with ChoiCo” activity plan for “Empathise & Understand” phase (Play mode) - NKUA0204

Finally, some teachers used already made online resources, online quizzes or questionnaires, for the “Empathise & Understand” phase, depending on the theme or the wicked problem of the DT activity and the learning objectives of the AP (Figure 38).

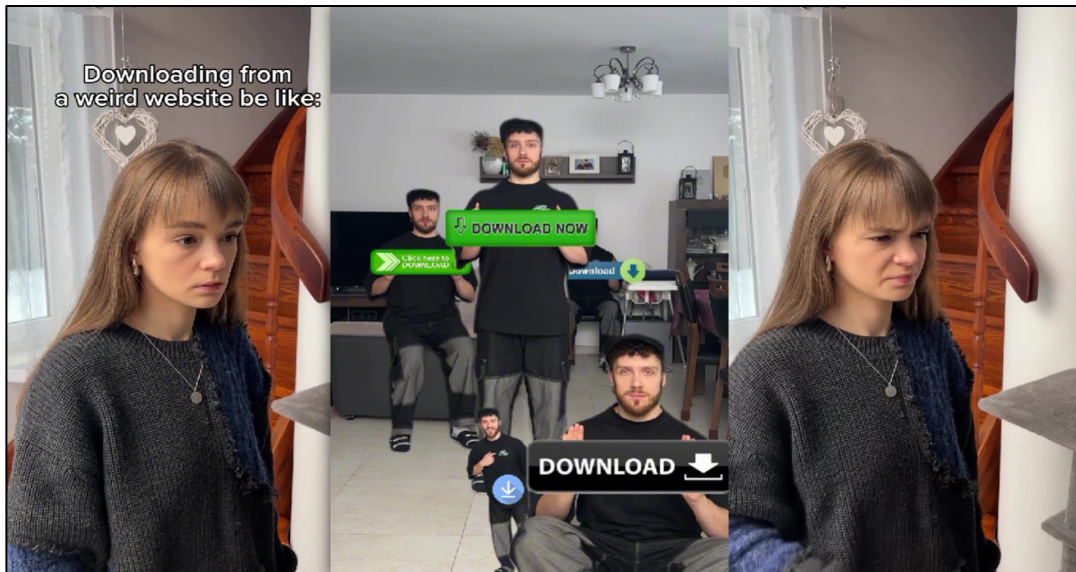


Figure 38: Screenshots taken from a video selected by the teacher for the “CyberSecurity” activity plan to be used for the “Empathise & Understand” phase - NKUA0203

## 4.4 Student Productions

In this section, we provide a brief overview of the artefacts that students created in physical or digital form during the DT projects. This includes the final products, which may be digital or physical in the case of 3D printing, but also artefacts students created or modified during the project, such as questionnaires, sketches and final posters or slide presentations to disseminate their work.

### 4.4.1 Physical constructions

In most cases, physical constructions were used by the students to communicate and reflect on their initial early ideas. They served as reference points to communicate, ask for feedback and reflect on their initial design ideas. During the different DT phases, students created handwritten lists, diagrams and sketches to structure their thoughts and ideas within the group or give feedback to other groups. This was done in parallel with the use of technology. A selection of examples of such constructions from seven (N=7) interventions is presented below (Figure 39 - Figure 50).

In “Sustainable Cities and Communities” (UGHENT0201) - about designing a sustainable living environment with specific attention to different groups of citizens of Ghent (e.g., elderly people) - during the “Empathise & Understand” phase, students brainstormed on paper on the needs of their specific group of citizens with respect to living in a sustainable city/community (Figure 39), and created a mind map with the main concepts related to the issue at hand. Some of these ideas fuelled the design of a ChoiCo game on this issue.



In the “Rapid Prototyping” phase, the same group made some mathematical assumptions and calculations on paper that fed the first attempts to create the code in the programming tool MaLT2 that would build their desired model. As shown in Figure 41, the students not only discussed the nature of the angles of their model, but also tried to think about and predict the path the avatar would take in the MaLT2 scene to create the correct sequence of commands, as indicated by the arrows they added to their handwritten drawing.

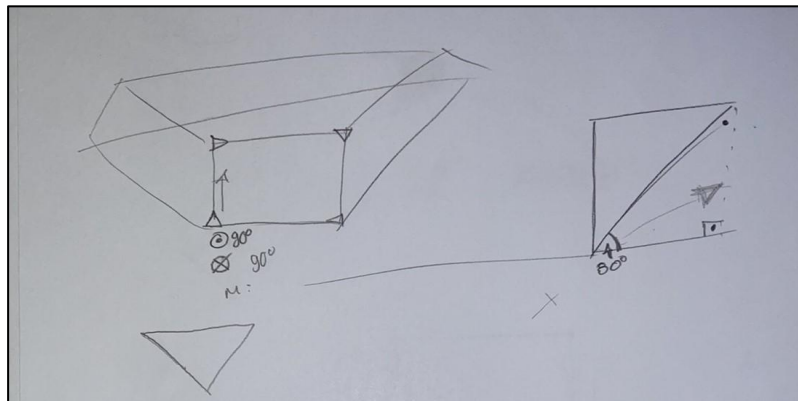


Figure 41: First steps of the model construction before creating it in the programming tool MaLT2 - NKUA0207

In ‘Fast Fashion’ (TCD0201) - trying to solve a fast fashion-related issue defined by the students themselves - a group of students created a ChoiCo game related to workers' conditions. The aim of the game was to make users experience what it is like to live as a low-wage factory worker and to think seriously about purchasing choices. As shown in Figure 42, the group created a rough sketch of the main game elements by defining the game fields, the values and some game rules. This design was fed into the game database during the “Rapid Prototyping” phase, where students also recorded the modifications they finally made.

2. Record edits or changes made to the game / product whilst your group was prototyping

	money	health	happiness	food	time alive
Restaurant stats	-30	15	20	388	5
Sweatshop stats	25	-40	-35	-30	10
Church	5	5	10	-10	5
Hospital	-50	10	-15	-10	5
Gym	-10	25	35	-25	5
Home	0	5	5	-5	1
Starting stats	100	100	100	100	0

added death messages e.g you are depressed  
starved to death

gives extra time because of work

Figure 42: ChoiCo database and students’ changes through iteration - TCD0201

Another example of students' physical construction from the same case, during the "Sharing and Feedback" phase, was the reflection points they had and the decisions they made about the final changes they wanted to make to their ChoiCo game, managing also the time they needed to make these changes (Figure 43).

**Final Workshop for Prototypes**

Think about what changes need to be made to your game and make a plan so it is completed by the end of class

Final steps	Time needed
More Points ✓	10 mins
Re balance Points	5 mins
Beat game	

Figure 43: ChoiCo database on the paper - TCD0201

Here, the reflection process followed the feedback students received from a peer review session. It was supported by feedback paper cards prepared by the teacher to provide feedback that was relevant and meaningful (Figure 44).

**Peer Review Session**

Members of group you are assessing:

Each group gives a 3-minute demonstration of their game and are marked as follows:

	Score (20)
ExtenDT2 game is appropriate for the end-users' needs	3 / 5
ExtenDT2 game works	4 / 5
ExtenDT2 game is appealing to the end-users	2 / 5
Information is well communicated	5 / 5

One suggestion or comment:

*Add more spikes & playability*

Figure 44: Feedback card/rubric - TCD0201

Another example of students' physical constructions after an early feedback Cycle between the "Define & Ideate" phase and the "Rapid Prototyping" phase is the case of 'Access Matters!' (NTNU0202 & NTNU0203) - about the construction of a sustainable school/classroom plan from an accessibility point of view - using VRobotics technology.

After their initial designs, students asked for and received feedback on their ideas and noted what could be improved to make changes to their designs before implementing them in the GearsBot interface (Figure 45, Figure 46).

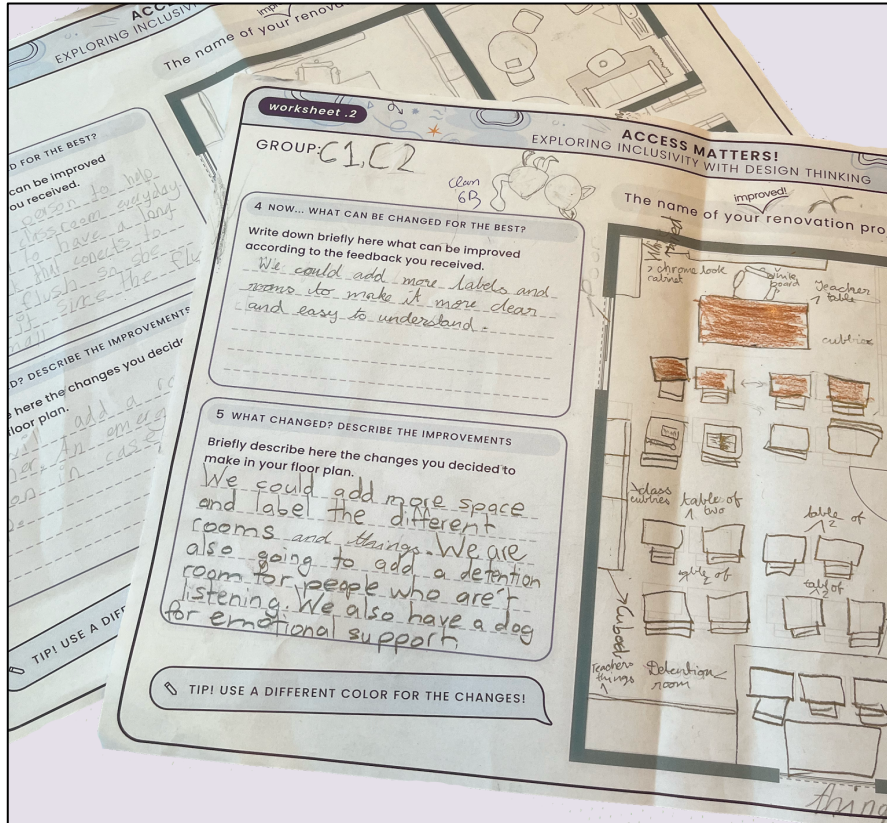


Figure 45: Notes after the first circle of feedback - NTNU0202

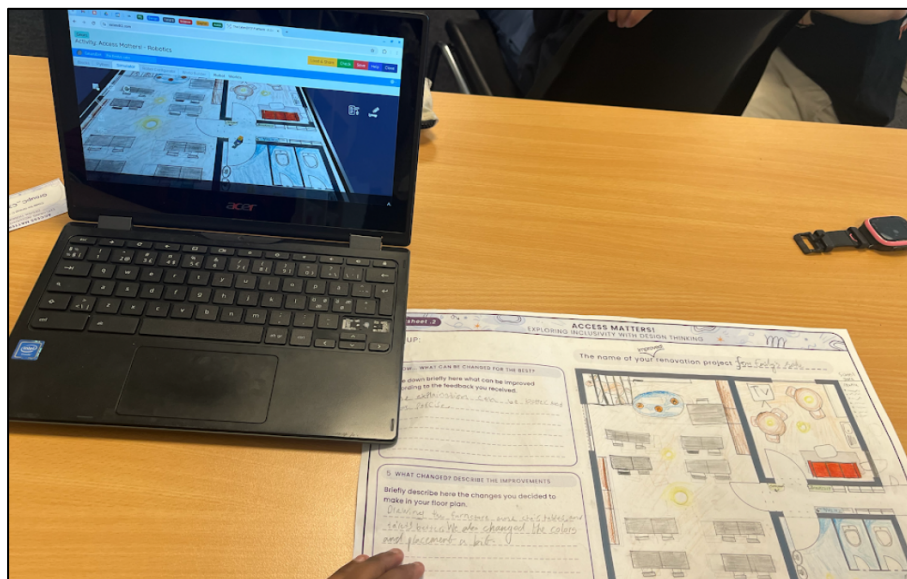


Figure 46: Implementing the new version of the school layout plan in the GearsBot interface after peer feedback - NTNU0203

Another category of students’ interesting physical constructions are the 3D printed objects from the MaLT2 tool created as part of “Jewellery and more” (NKUA0201), “Personalised items” (NKUA0207) and “Make Puzzles” (NKUA0208). Students used 3D printing as a feedback mechanism for their designs during the iterative Cycles of the “*Rapid Prototyping*” phase, producing a variety of prototype models. This allowed them to reflect on their current designs and modify their models if the result was not satisfactory. As an example, a group working on the “Personalised Items” case (NKUA0207) designed a cylindrical model that could be used either as a decorative bottle decorated with a geometric shape (triangle) if printed in large dimensions, or as a ring or bracelet with the Greek letter delta ( $\Delta$ ) if printed in a smaller size (Figure 47). A prerequisite for this idea and its construction was the creation of a code in MaLT2 containing variables so that the shape could easily be dynamically modified and the desired model printed.

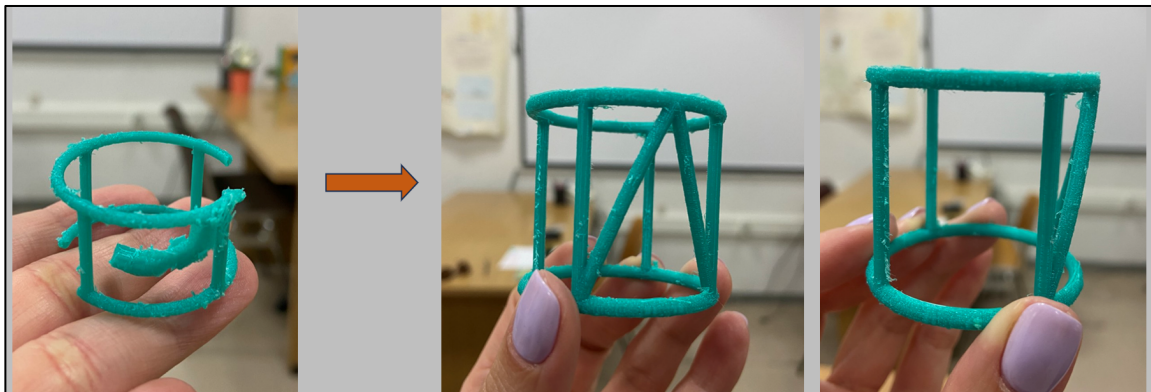


Figure 47: 3D-printed models of a cylindrical decoration - NKUA0207

Below we present more examples showing both the final student models and some physical prototypes printed during the prototyping phase (Figure 48, Figure 49, Figure 50).

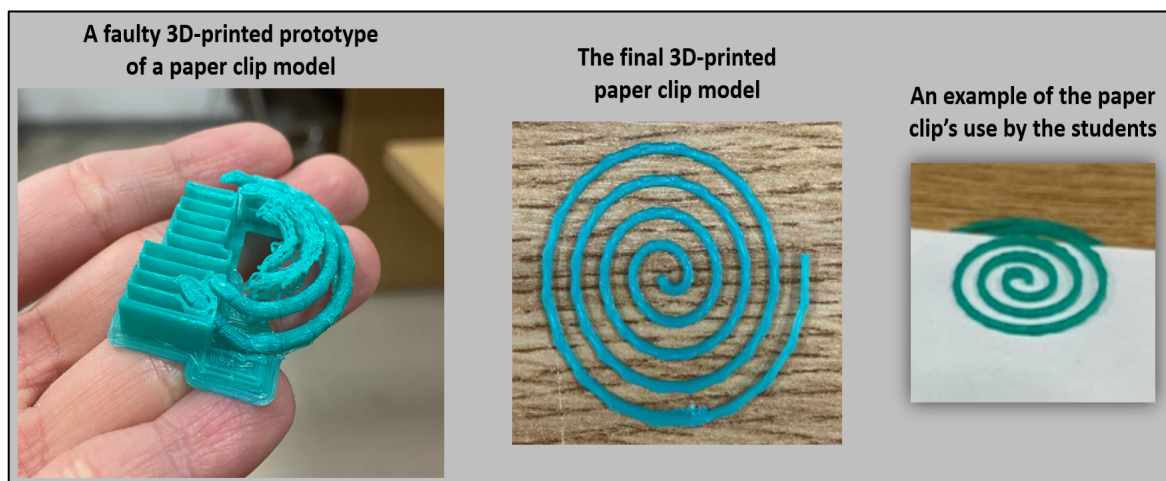


Figure 48: 3D-printed models of a paper clip - NKUA0207



Figure 49: 3D-printed models of jewellery (prototypes & final models) - NKUA0201

+

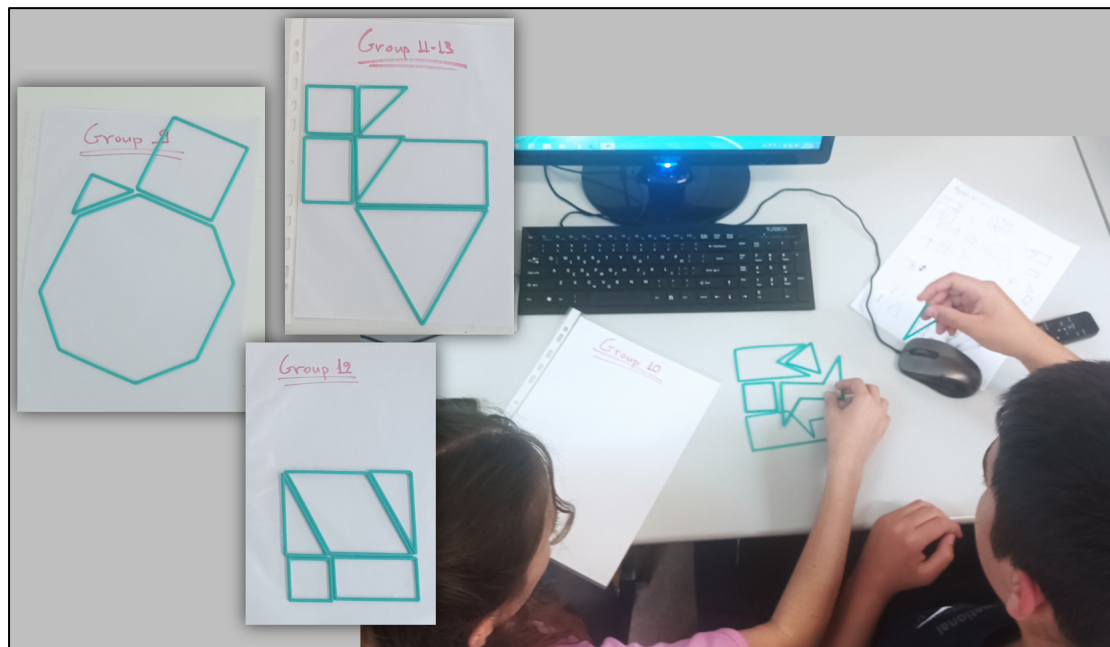


Figure 50: 3D-printed puzzles - NKUA0208

Students' final 3D constructions were used during the *“Respond & Deliver”* phase where students presented their artefacts and shared the design process with their audience (e.g., school, classmates, parents).

As shown, physical constructions were created by the students at all stages of the DT process, depending on the design of the activity plan of each intervention and the emerging needs of the students for handwritten sketches, lists and notes to help them in the next steps of their projects.

#### 4.4.2 Digital constructions

In this section students' digital constructions are presented under four categories:

1. Final products/artefacts: the final SorBET and ChoiCo games, GearsBot simulations and MaLT2 digital models to be printed
2. Rapid prototypes: rapid prototypes students created before the finalisation of artefacts, focusing on their iterative refinement
3. nQuire missions
4. Respond and Deliver digital constructions

#### Final products

The aim of all DT projects was to develop a digital product as a solution to the problem or challenge at hand, using the project technologies. This product was either a digital game in the case of ChoiCo or SorBET, a digital 3D model that could be 3D printed in the case of MaLT2, or a virtual robotic simulation in the case of GearsBot. The students' digital constructions included online missions in nQuire, digital games in SorBET and ChoiCo, virtual robotics simulations in GearsBot, and digital models in MaLT2 that would be 3D printed. In Year 2 interventions, students used the emerging technologies that had been developed, as part of WP4, i.e., hand recognition in SorBET, geolocation and Google maps integration in ChoiCo and 3D printing in MaLT2 (see D5.4) to create multiple prototypes of their artefacts. Although the students in each intervention dealt with the same social science issue (e.g., cybersecurity, design of personalised items and jewellery, environmental issues or different issues of sustainability), the groups developed quite different final products.

For instance, in the *“Fast Fashion”* project, each group created a digital game in ChoiCo or SorBET, as they were free to choose one of the Exten.(D.T.)<sup>2</sup> technologies in this case. Their games dealt with fast fashion issues, but from different angles, such as public awareness of fast fashion issues, the working conditions of workers, or the environmental impact of fast fashion production (Figure 51, Figure 52, Figure 53, Figure 54).

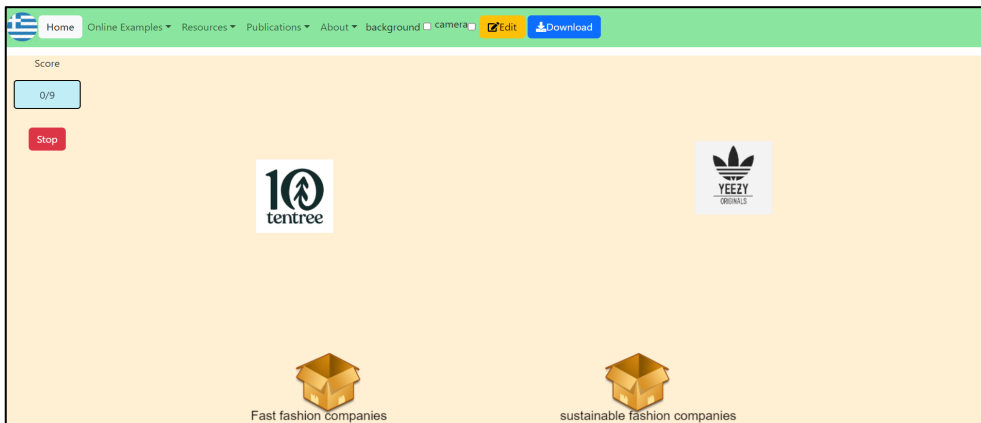


Figure 51: A Screenshot of a SorBET game about Fast fashion & Sustainable fashion companies (play mode) – TCD0201

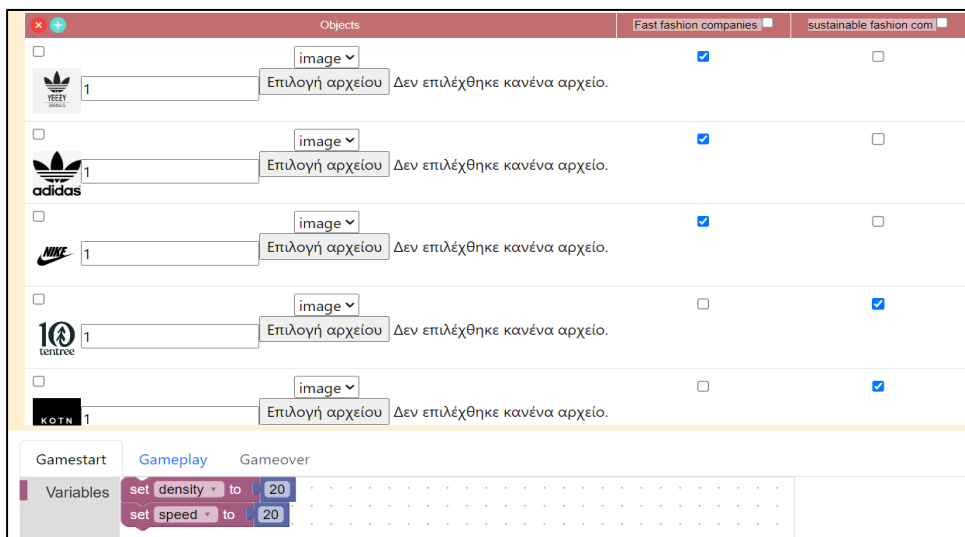


Figure 52: The design behind the SorBET game about Fast fashion & Sustainable fashion companies (edit mode) - TCD0201

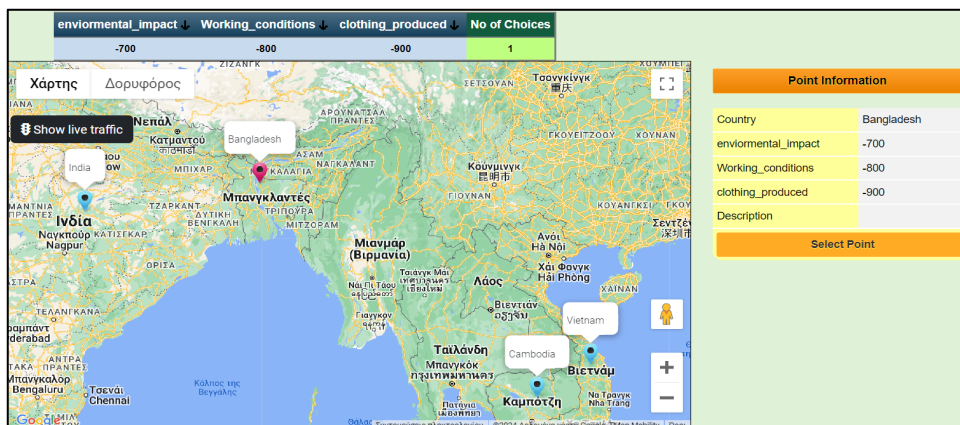


Figure 53: A ChoiCo game about fast fashion production using the emerging technology of geolocation - TCD0201

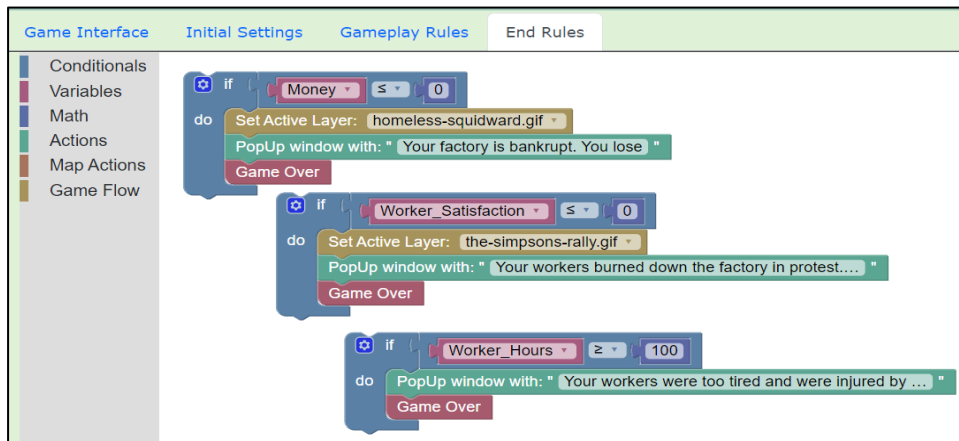


Figure 54: A screenshot of the End Game Rules from the ChoiCo game about the choices of an employer in fast fashion production - TCD0201

A similar case of an intervention where students worked on the same social science topic, but groups created quite different final games, was with the DT project “Entrepreneurship” that took place in a vocational school. Students designed a ChoiCo game that simulates the practice of being an entrepreneur, such as making crucial decisions that affect the sustainability and success of their business. Another group of students created a ChoiCo game (Figure 55) about places that provide car service and spare parts for different car brands. Using the emerging technology of geolocation, the value of travel time in the game changes and depends on the real time of travel time between the points in the ChoiCo scene - representing real places in the city of Athens - as provided by Google maps. Additionally, in the design of the game, to present a challenge that exists in similar real situations, the students choose to use the 'random' command about the quality of the spare parts that can be found in these places.

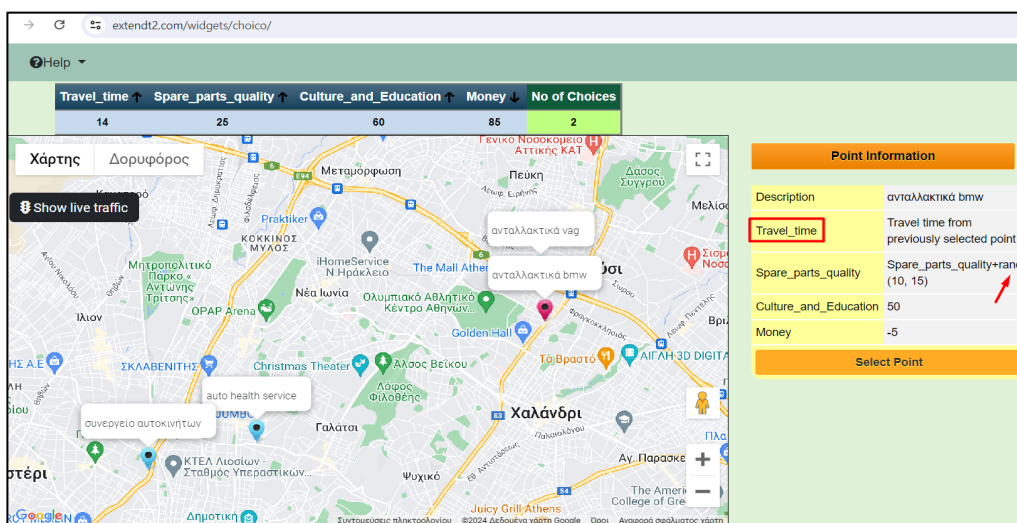


Figure 55: A screenshot of the ChoiCo game from the DT project “Entrepreneurship” (the case of car service) with the affordance of geolocation - NKUA0205

Another group on the same intervention created a ChoiCo game with the case of their own school, where they added points representing their classrooms, their subjects (e.g., maths, physics, Greek language, history), the balcony, the schoolyard, the canteen and the choices in the canteen (e.g., croissant, sandwich, juice, water), etc. (Figure 56, Figure 57, Figure 58). The values of the game that the group chose to add were joy, socialisation, money, knowledge, energy as well as the number of absences from class. As the intervention (NKUA0205) concerned issues of entrepreneurship, students initially designed a game where the player would be responsible for the canteen of the school. However, during the design process they decided to change the game idea and create a game that addressed the consequences of the daily life of the students at the school. Students thus interestingly reflected on real life situations and choice consequences leading to interesting discussions about daily issues with which they could themselves relate to in personal ways.



Figure 56: A screenshot of the ChoiCo game from the DT project “Entrepreneurship” (the case of their own school) with the affordance of geolocation in satellite view - NKUA0205

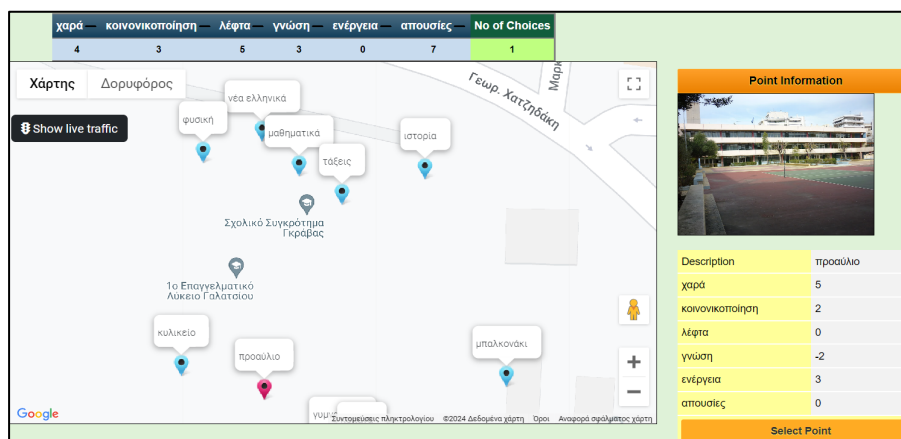


Figure 57: A screenshot of the above ChoiCo game from the DT project “Entrepreneurship” (the case of their own school) with the affordance of geolocation in simple view - NKUA0205



Figure 58: A screenshot of the Gameplay Rules from the above ChoiCo game from the DT project “Entrepreneurship” (the case of their own school), where students used a variety of conditionals, variables and game & map actions - NKUA0205

Figures 59 - Figure 65 show selected student digital productions from Year 2 interventions.

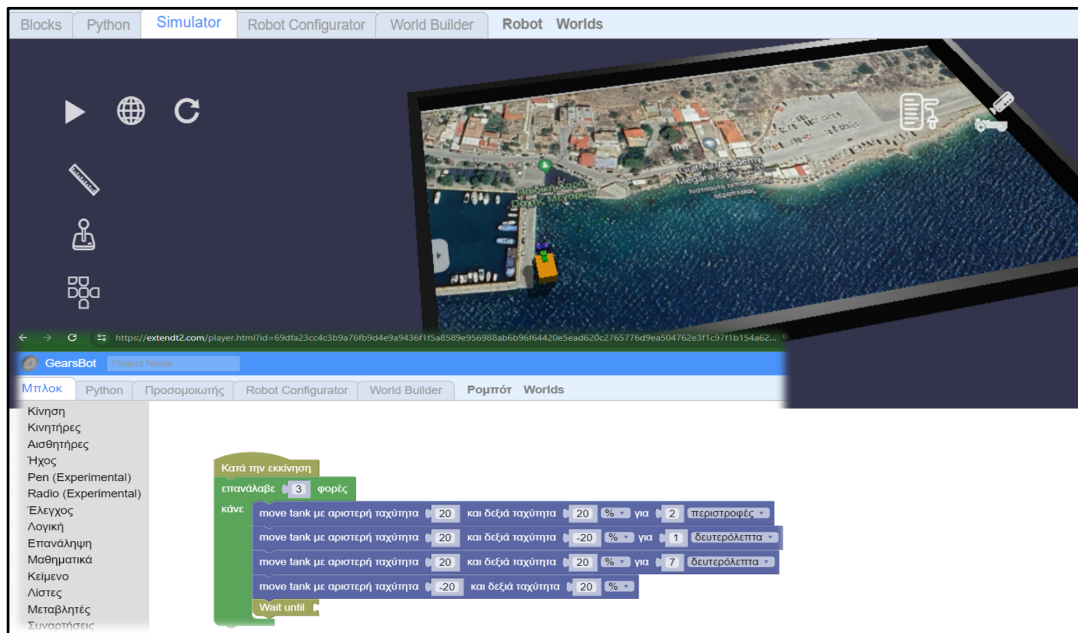


Figure 59: Screenshots of the Simulator and Blocks tabs in GearsBot from the DT project “Cleaning Robot for the shores” tackling coastal pollution during the busy summer months (the case of beach in Megara, Greece) - NKUA0206



Figure 60: Screenshots of the Simulator and Blocks tabs in GearsBot from the DT project “Recycling” - NTNU0204

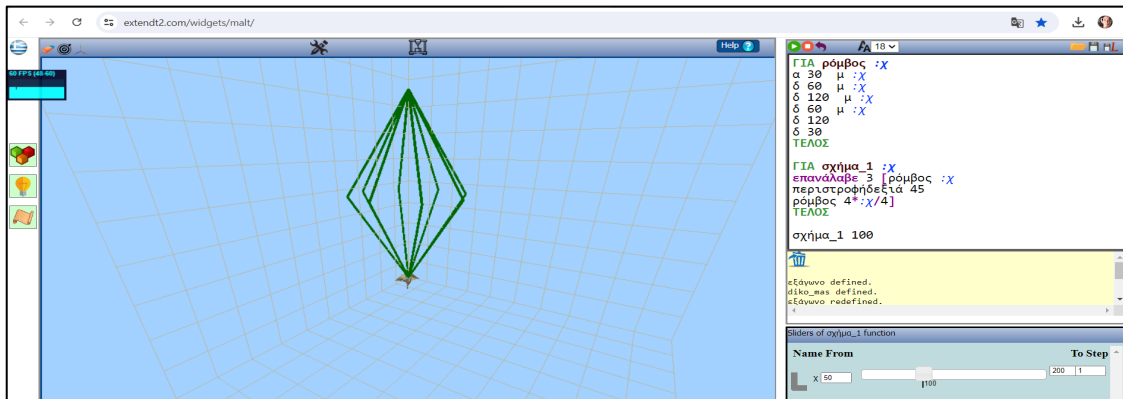


Figure 61: The digital model of a diamond from the DT project “Jewellery and more” - NKUA0201

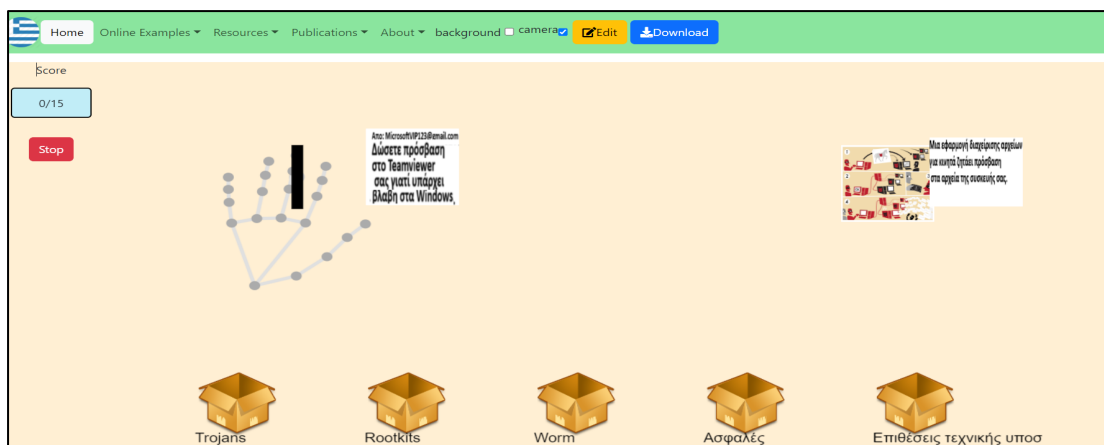


Figure 62: A screenshot of the SorBET game from the DT project “Cybersecurity” with the embodied feature of hand movement about the issue of firewall - NKUA0203

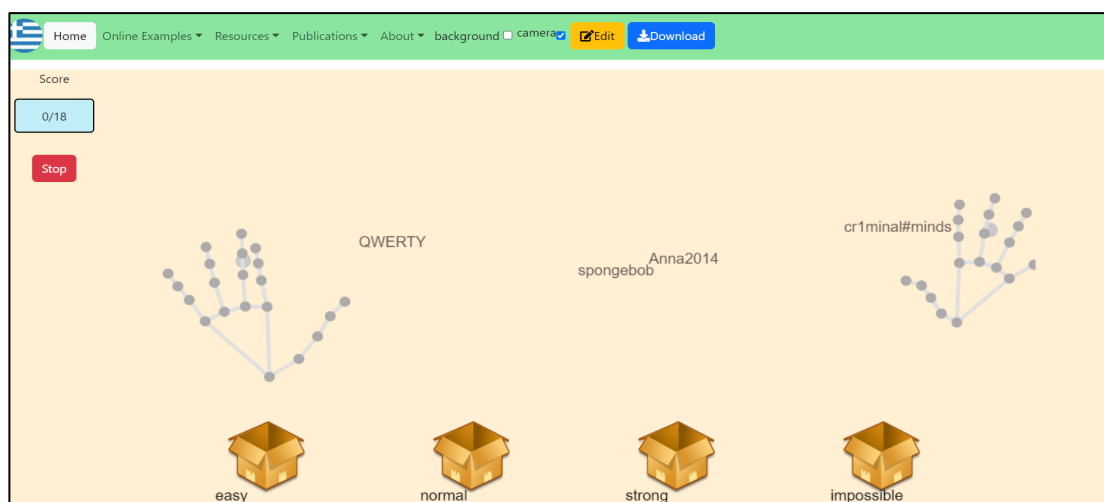


Figure 63: A screenshot of the SorBET game from the DT project “Cybersecurity” with the embodied feature of hand movement about the issue of strong passwords - NKUA0203

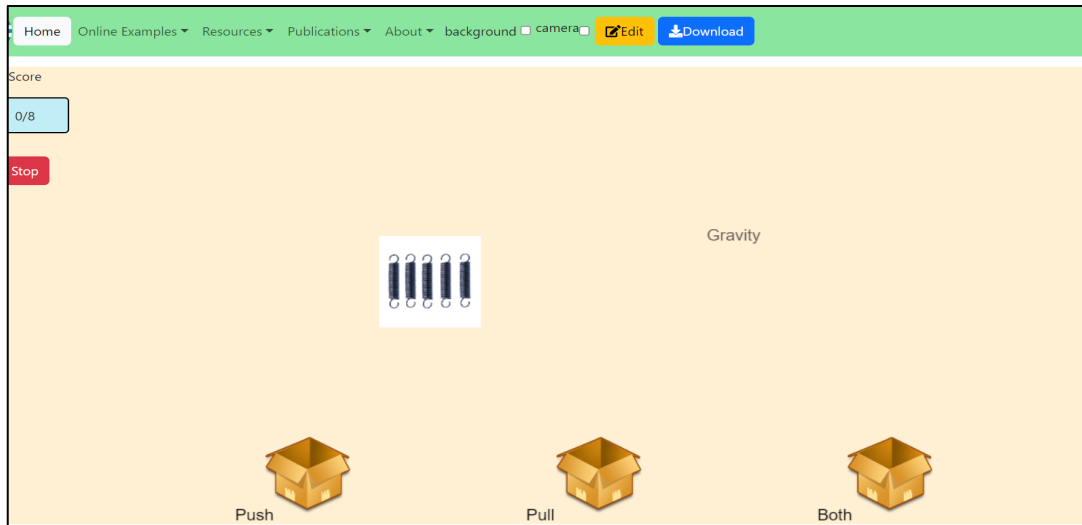


Figure 64: A screenshot of a SorBET game from the DT project “Types of Forces” - OU0202

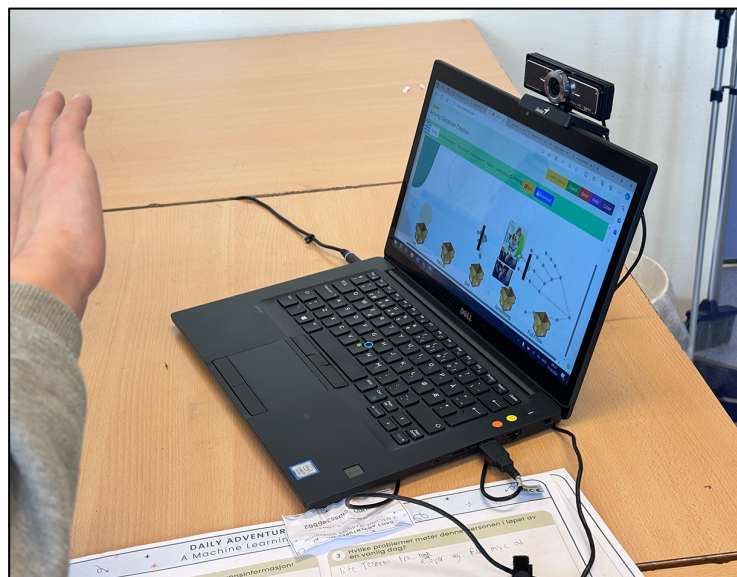


Figure 65: A SorBET game from the DT project “Learning about AI” with the new feature of hand recognition - NTNU0205

### Rapid prototypes and iterative refinement

Following an iterative design process, students created several 'rapid prototypes' before developing the final artefact, particularly in the case of the ChoiCo, SorBET and MaLT2 technologies. The advanced computational affordances of these tools allowed students to consistently create, test and modify prototypes of their games or models. For example, during the DT project “Personalised Items”, students in the same groups created several different versions of the 3D constructions in MaLT2 before arriving at the final result (Figure 66, Figure 67), which they could easily track in the ExtenDT2 platform in order to reflect on previous prototypes and proceed with further modifications.

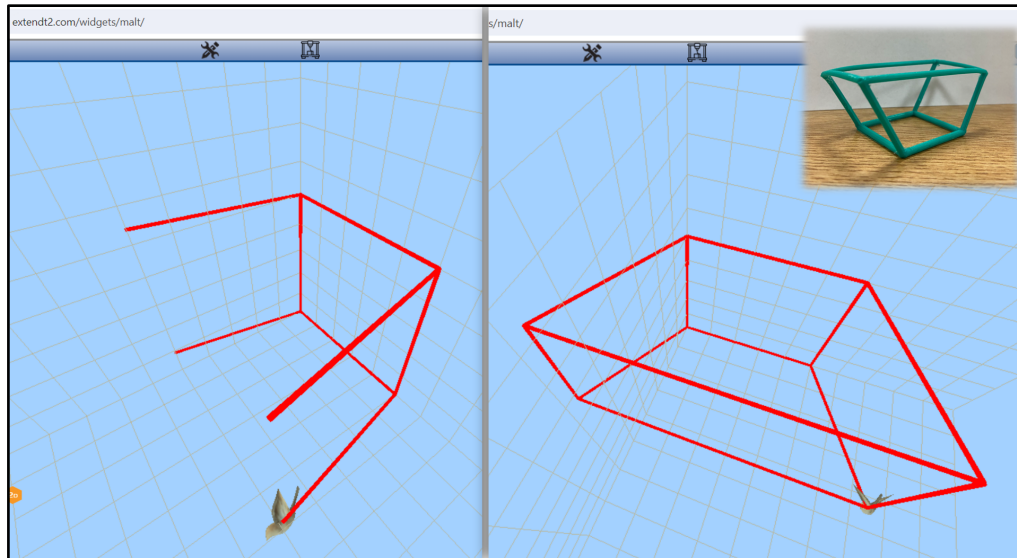


Figure 66: Screenshots of different prototypes of a customized holder for post-its of different sizes in MalT2 from the DT project “Personalized Items” - NKUA0207

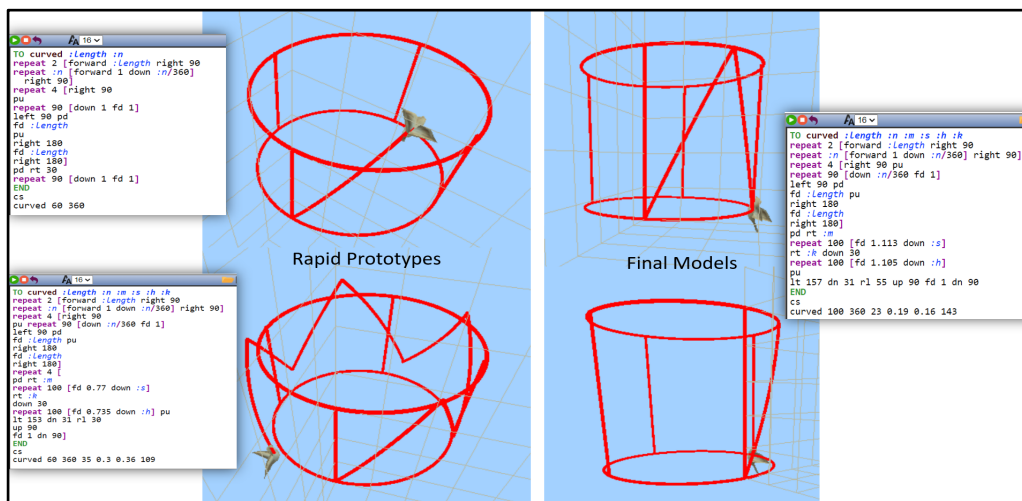


Figure 67: Screenshots of different prototypes of a cylindrical decoration with multiple uses in MalT2 from the DT project “Personalized Items” - NKUA0207

### nQuire missions

Students also created online questionnaires (missions) in nQuire (Figure 68, Figure 69, Figure 70) to collect data from others. During Year 2 of school interventions, a total of 81 nQuire missions were created. As also mentioned earlier (Section 4.3.3. ‘Technology use’) in thirteen (N=13) interventions students used nQuire during the “Sharing and Feedback” phase, while in eight (N=8) interventions integrated the tool into the “Empathise & Understand”. The missions for the “Empathise and Understand” phase enabled students to gather information about their audience needs and preferences regarding the issue at hand. The missions for the “Sharing and Feedback” phase included links to the groups’ games or models, extracted by

the ExtenDT2 platform. Users were asked to test these and provide feedback by answering questions to suggest improvements.

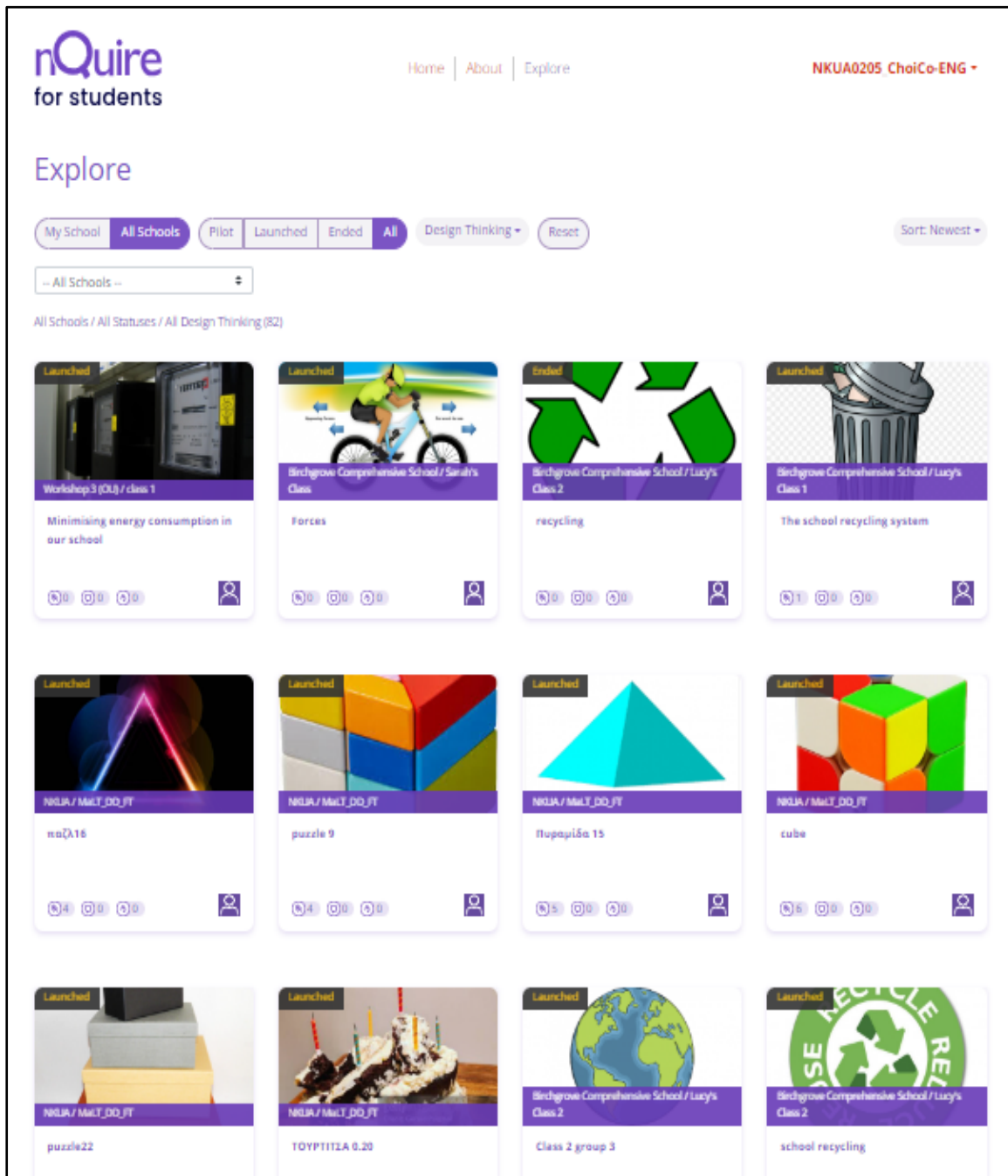


Figure 68: nQuire missions created by students during the “Empathise and Understand” and “Sharing and Feedback” phases

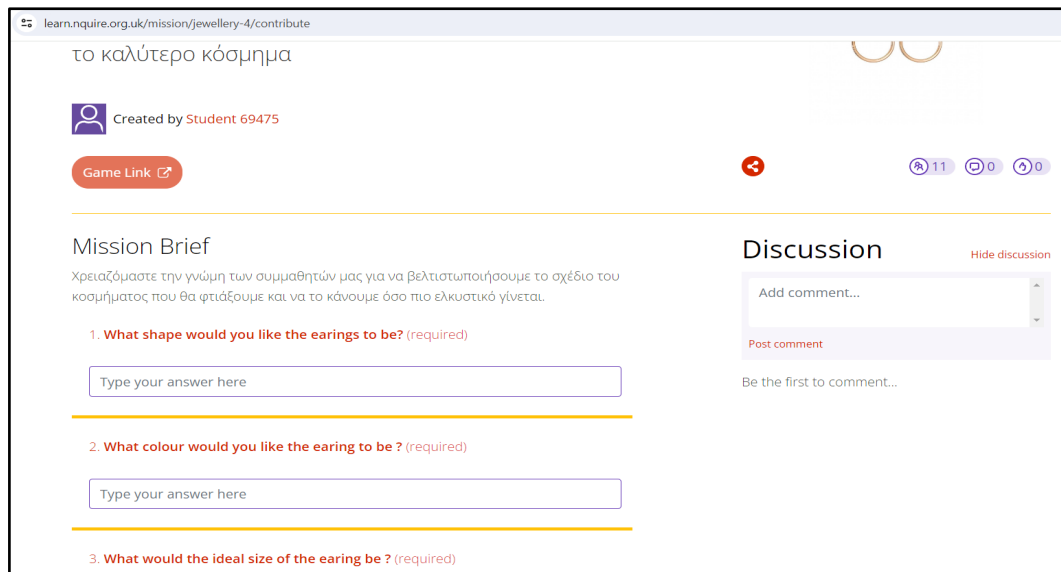


Figure 69: An nQuire mission created by students for their jewellery model in MaLT2 during the “Empathise and Understand” phase - NKUA0201



Figure 70: An nQuire mission created by students for their SorBET game during the “Sharing and Feedback” phase - OU0202

### Respond and Deliver digital constructions

Finally, in some interventions, during the “Respond & Deliver” phase students created digital posters or slide presentations to share their work with their audience (Figure 71, Figure 72). In this phase, students presented their work in the classroom or uploaded their posters to the classroom or school website together with their final digital product (game, 3D model, photos of 3D printed objects). The activities of this DT phase aimed at enhancing students’ communication and dissemination skills.



Figure 71: Posters created by students in the DT project “Cybersecurity” to promote their games on the issues of strong passwords and phishing - NKUA0203



Figure 72: Slide presentation created by students in the DT project “Personalised Items” to promote their product by also presenting the process of its construction (code-digital model-3D printed object) - NKUA0207

## 5. Reflection on Year 2 School Interventions

In this section we provide some reflective insights regarding Year 2 school interventions implementation as emerged from the preliminary analysis of the collected data shared with WP7, and from the analysis of the APs. The detailed results of Year 2 interventions evaluation and analysis will be presented and discussed in D7.2 as part of “Cycle 2 Evaluation Report”.

### 5.1 Feedback

In Year 2 emphasis was given in feedback processes during DT activities. Both teachers and students commented that the “Sharing and Feedback” phase was a valuable part of the design thinking process. Indicatively, a Greek teacher (NKUA0204) commented that *“the most valuable thing that happened I guess was that students engaged in feedback. Students are evaluated in school in general but not from their peers. I saw that by sharing with others something of theirs that they created having as a final goal to improve it, made them think thoroughly about how to express themselves, how to improve the way they communicate both their creations and their feedback to others”*. Similarly, a student from NKUA0205 intervention shared in the interview that, *“it was nice that we had the chance to improve ourselves. Most of the times teachers tell us our mistakes and then we go on. Now we had to think about it actually, because the final goal was to create a good game not a boring one, so I would say that I learnt how to listen during the feedback activity”*.

As commented in Section 4.3.2, feedback was not only part of the “Sharing and Feedback” phase rather an ongoing process throughout the activities, bringing forward needs and preferences of others as the main criteria for the design decisions taken. Students were engaged in feedback sessions after the “Define and Ideate” phase or during the “Rapid prototyping and Iteration” phase. Receiving feedback on their design ideas or mock-ups with others before or during the “Rapid prototyping and Iteration” phase allowed students to integrate more of their peers' ideas in their designs while their prototypes were still in their early development stages. It also facilitated the formation of meaningful questions for the creation of nQuire questionnaires.

Students provided feedback to their peers in various forms including online written and oral feedback. Online feedback was through with the use of nQuire. In these cases, students shared the link to their artefact in an nQuire mission along with two or three questions for their audience. While using the nQuire platform for feedback (see NKUA0204 & MaLT2 cases) students were restricted in forming the right questions - something often really challenging especially for the younger ones. Most of the questions students used in these missions were quite generic and they often did not help students make decisions regarding the improvement of their artefact. On the contrary, oral feedback sessions during the rapid prototyping phase, while students were physically in the classroom provided the setting for meaningful communication enabling immediate responses and valuable discussions between members

of different groups (e.g. NKUA0203, NKUA0205) (Figure 14). Expressing directly their thoughts to their peers resulted in an immediate response and thus interesting discussions emerged where students expressed themselves more precisely. In cases where written feedback was provided teachers' material structured the process. Students were provided with feedback worksheets designed to help aid with returning feedback comments back to their peers.

A special case involved feedback in the 3D printing cases, where students had to create digital models first and then print them. Given that printing 3D models take time and could not be done directly at school, it was necessary to initially share their digital artefacts. Students could then apply the feedback received to finalise the digital models which they then printed.

## 5.2 External Actors' Involvement

An additional element regarding feedback was the involvement of external actors as reviewers of students' work. In NKUA0201, NKUA0207 and NKUA0208 students received feedback on their 3D models from friends and family, while in NKUA0205 and NKUA0206 students interviewed students of other classrooms in their school on their ideas during school breaks. In UGHENT0201 students conducted interviews in the streets to understand problems related to the environmental sustainability of their city as experienced by citizens themselves.

## 5.3 Introductory - Supporting Activities

Apart from the main processes described by the DT phases, most of the activity plans included activities that were not related to the DT issue but aimed to facilitate students' introduction to the technologies of the project as well as the DT methodology.

### 5.3.1 Technologies

In most cases the need to include activities that aimed for students to get familiar with the technology they would use emerged. These activities mainly included the use of already existing, often 'half-baked' artefacts with students experimenting to understand the main functionalities of the digital environments. Teachers integrated these activities into or after the "Empathise and Understand phase". In TCD cases the teacher added a "Sandbox" activity in the project which was devoted exclusively to students getting to know the technologies they could choose to use.

### 5.3.2 Design Thinking

Other introductory activities were related to DT methodology. These usually included teachers' presentations on the process students were planning to follow during the project (see NKUA0203). By informing the students about the phases, processes and tools they served as learning objectives related to DT with innovative technologies and encouraged reflection, facilitating at the same time knowledge of DT (See D7.1, p37).

## 5.4 Assessment Methods and Tools

An issue of main concern for both teachers and researchers in Year 1 was assessing learning outcomes. In Year 2 we aimed to address the challenge by encouraging teachers to formulate learning outcomes using learning objective verbs and linking each one of these with specific assessment tools and methods (section 2.1 of the AP template). As a result, in Year 2 teachers had a variety of tools to assess students' learning outcomes including:

- Students' artefacts regarding specific elements (e.g., conditional commands in the code in NKUA0205, mathematical properties integrated in MaLT2 programming procedures in NKUA0207 and NKUA0208) as well as their gradual refinement through iterations Cycles as extracted by the "Load & Share" button of the ExtenDT2 platform
- Worksheets (e.g. NKUA0202)
- Teacher and self-assessment rubrics (NTNU0204, NTNU0205, NTNU0206, NTNU0207, NTNU0208, NTNU0209, UGHENT0201)
- Pre- and post-quizzes (NTNU0204) designed by the teachers and e) teacher's notes and observations
- Interventions in the form of targeted questions, intriguing students to discuss their actions and contributions to the process, giving at the same time chance for reflection during the activity (NKUA0201, NKUA0207, NKUA0208, OU0201)

Recognising that assessment is a persistent challenge in educational activities with open ended and iterative nature such as DT activities, our aim is to further enrich the assessment processes by incorporating the learning analytics dashboard to capture specific student interactions with the technology and report their progress throughout the DT activities in a graphical way.

## 5.5 Learning Outcomes

The learning outcomes observed during Cycle 2 of school interventions focused on several Design Thinking and innovative technologies related learning outcomes that differed from Year 1. Firstly, there was a strong emphasis on students' ability to develop rapid prototypes through iterative design. Secondly, the interventions placed a significant focus on students' ability to analyse information and interpret data collected, often through the nQuire questionnaires, to better understand user needs. In addition, the learning outcomes highlighted students' ability to interpret and proceed with reflection and feedback, discussing, deciding, and planning modifications to their artefacts based on the feedback received from their peers. These points of focus resulted in a more user-centric approach adopted by the students where understanding of other points of view is essential for creating meaningful solutions.

These changes in the learning outcomes focus are likely to be related to the new Exten.(D.T.)<sup>2</sup> Design Thinking model to which the Year 2 interventions were structured. The model aimed to promote tacit processes of the DT methodology such as providing meaningful feedback and incorporating others' feedback for prototypes refinement.

Another interesting differentiation that emerged is related to the 21<sup>st</sup>-century skills learning outcomes. While collaboration-related skills were the most frequently mentioned in Year 1 APs, in Year 2 Communication followed by the skill of Presentation were the most noted. Presentation skills were not mentioned at all in Year 1 APs. This variation can also be attributed to the new DT model where in the last phase, where students present their final artefacts, was changed from "Deliver" to "Respond and Deliver". In the new DT model, students during the last phase not only present their artefacts but also refer to the process of design, including in their explanations during presentation about what kind and for which reasons they decided either to integrate or reject others' feedback in their designs. This provided teachers with the context to set communication and presentation related learning outcomes and students' assessment. Presentations were often followed by questions from the audience and discussions. Thus, the process was more interactive and as a result more engaging for the students.

A noteworthy observation regarding learning outcomes was that Reflection and Critical Thinking were mentioned in multiple learning outcomes categories by teachers. In This is not so unexpected if we consider in that even in the literature, skills like collaboration, critical thinking and reflection are referred to as both 21<sup>st</sup>-century skills and DT skills. For example, Kennedy & Sundberg (2020) refer to critical thinking as a 21<sup>st</sup>-century skill, whereas Ananda et. al. (2023) associate critical thinking with DT processes like framing the problem, self-regulation and reflection. In cases when reflection and critical thinking were related to the integration of others' feedback in their prototypes, these skills were included in the Digital Skills category. Yet when these skills were associated with reflecting on the DT issue at hand and others' needs, these skills were included in the DT with ET related learning outcomes.

## 5.6 Multiple Entry Points

A further insight that emerged by the detailed review of the activity plans and inspired one of our future steps (see Section 6) was that teachers, without explicitly mentioning it, integrated in the DT activities multiple entry points for their students to reassure equal engagement and opportunities for contribution for all. These were related to: a) technology use, b) grouping and orchestration, c) integration of unplugged activities, and d) openness of the project regarding tool selection and DT problem definition.

### 5.6.1 Technology Use - related entry points

In activities where participants lacked previous experience with digital tools, teachers included ‘sandbox’ activities in their plans (TCD0201, TCD0202). These activities allowed students to experiment with technology in a low-pressure environment. Additionally, supporting materials like exemplary games, which students could modify to understand tool functionalities, were provided (NKUA0205, NKUA0206). This approach helped students gain confidence in using technology, enhancing their engagement and creativity during the project.

### 5.6.2 Grouping and orchestration

A crucial grouping criterion that teachers often used was the complementarity of group members regarding school performance or digital skills (UGHENT0201, UGHENT0203, OU02011, OU0202), promoting equal participation. Supporting materials that guided role distribution and team management were also included. Interviews revealed that students naturally divided tasks based on individual strengths, with those skilled in programming handling technical aspects and those with strong presentation skills taking the lead during the “Respond and Deliver” phase. This complementary grouping ensured balanced participation.

### 5.6.3 Unplugged activities

Unplugged activities, such as ideation through mind mapping (e.g., UGHENT0201) and prototyping through sketching (e.g., in NKUA0207) provided alternative entry points, allowing less confident technology students to express their ideas and contribute equally, ensuring that everyone contributed to the DT process. Designing supporting materials that suited student needs, prior experiences and preferences, such as reflection cards for younger students (e.g., NTNU0201), peer feedback worksheets (e.g., UGHENT0203) or ready-made nQuire questionnaires created by the teacher for students to give feedback after the ‘Define & Ideate’ phase (e.g., NTNU0209), enabled all students to communicate their ideas in familiar ways.

### 5.6.4 Openness in project design

This approach encouraged students to make their own decisions, making the projects more engaging and interesting. It was particularly beneficial for students who typically do not participate actively in class, as it encouraged them to develop decision-making, self-regulating skills and take ownership of their learning.

These multiple entry points played an important role in engaging students with diverse skills and confidence levels, ensuring their meaningful participation.

## 6 Conclusion and Future Steps

Year 2 of the school interventions revealed critical insights into the implementation of Design Thinking (DT) with the use of emerging technologies in educational settings. Feedback emerged as a vital component, integrated throughout various stages of DT processes and provided in various formats, with oral feedback proving particularly effective. Introductory activities were integrated by teachers to support their students familiarise themselves with technologies and DT methodology. In addition, a variety of assessment methods was implemented including rubrics, students' artefacts, teachers notes and worksheets, while key learning outcomes included improved rapid prototyping, data analysis, and feedback integration. A notable shift was observed in the emphasis on communication and presentation skills, driven by the new Exten.(D.T.)<sup>2</sup> model. This model facilitated a user-centric approach and encouraged students to articulate their design processes and decisions highlighting the importance of continuous feedback and effective communication during DT activities.

Next steps include:

- Further simplification of the co-design and implementation process, meaning further simplification of the Activity Plan Template and less credentials used by teachers and students during the process.
- Integration of multiple entry points, aiming to support equal participation for all students in DT activities with emerging technologies. This includes the adjustment of the activity plan template to offer multiple paths for students according to their specific needs and characteristics, the design of supporting material that can be used either for the students to familiarise with project's technologies in ways that serve their project's objectives or to express themselves in alternative ways (e.g., mind map boards).
- Integration of Authorable Learning Analytics (ALA) of the ExtenDT2 platform which will be designed to provide visualised data about students' engagement and progress in real time, supporting teachers in monitoring and assessing groups' progress through the different DT stages.

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